This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

QE
261
.A3

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

FOR

1901.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
BY WYMAN & SONS, LIMITED, FETTER LANE, E.C.

And to be purchased from
E. STANFORD, 12, 13, and 14, LONG ACRE, LONDON;
JOHN MENZIES & Co., ROSE STREET, EDINBURGH;
HODGES, FIGGIS & Co., GRAFTON STREET, DUBLIN;
From any Agent for the sale of Ordnance Survey Maps; or through any Bookseller from the Ordnance Survey Office, Southampton.

1902.

Price One Shilling.

Digitized by Google

Digitized by Google

CONTENTS.

PAGE

INTRODUCTION BY THE DIRECTOR 1

I. ENGLAND AND WALES.

I. FIELD-WORK 4

1. Midland District 5

2. Southern District 16

3. South Wales District 34

4. Examination of new Railways and other Sections ... 53

Notes on a new Railway in course of construction between Axminster and Lyme Regis 53

Further notes on the cuttings along the South Wales Direct Railway 59

Report on the Examination of the Sections at the Reservoirs, and along the course of the Aqueduct of the Birmingham Corporation Waterworks, Rhayader to Frankley 60

Notes on the Goole and Marshland Light Railway ... 64

II. PETROGRAPHICAL WORK 65

Rocks of the Southern Highlands 65

III. CHEMICAL WORK 71

Analytical methods in use in connection with the examination of South Wales Coals 73

Rottenstone from South Wales 80

Weathering of Magnesian Limestone 83

Minerals from Skye and Ross-shire 86

Tertiary Igneous Rocks from Skye 87

Rock from Newlyn, Cornwall 88

Pseudogaylussite from the Clyde 89

IV. PALÆONTOLOGICAL WORK 91

List of Specimens in Museum recently figured 93

V. MUSEUM OF PRACTICAL GEOLOGY 93

VI. MAPS, SECTIONS, AND MEMOIRS, PREPARED AND PUBLISHED 94

II. SCOTLAND.

I. FIELD-WORK 95

1. Northern District 95

2. West Highland District 118

3. East Highland District 157

II. PALÆONTOLOGICAL WORK 177

Notes on Carboniferous Plants collected in Berwickshire 179

A new species of *Gyracanthus* 181

List of Specimens in the Survey collection recently figured 182

Digitized by Google

CONTENTS—*Continued.*

II. SCOTLAND—*Continued.*

III. MUSEUM WORK ... ...
IV. MAPS, ETC., PUBLISHED ... ...

III. IRELAND.

I. FIELD-WORK ... ...
Dublin District 1-3

II. MAPS PUBLISHED 199

APPENDIX : A. CATALOGUE OF TYPES AND FIGURED SPECIMENS OF BRITISH FOSSIL PHYLLOCARIDA PRESERVED IN THE MUSEUM OF PRACTICAL GEOLOGY, LONDON 200

„ B. CATALOGUE OF TYPES AND FIGURED SPECIMENS OF BRITISH PALÆOZOIC ECHINODERMATA PRESERVED IN THE MUSEUM OF PRACTICAL GEOLOGY, LONDON 204

INDEX 212

ILLUSTRATIONS.

Fig. 1. Section south-west of Shools Farm, near Axminster . 54

Figs. 2 and 3. Railway cutting north-east of Great Trill, near Axminster 55

„ 4 and 5. Sections near South Ground, Linhay, south of Axminster 56

Fig. 6. Section east of Combe Pyne Station 58

„ 7. Cutting west of Bradfield Farm, Hullavington 60

Digitized by Google

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1901.

INTRODUCTION.

The field work for the year 1901 was concentrated in definite areas and was placed under the charge of District Geologists. In view of this method of carrying on the work it has been thought desirable to make the annual record of progress reflect the organisation of the Survey. The chronological arrangement which has been adopted in previous *Summaries* has therefore been abandoned in favour of a geographical arrangement. Mr. Teall.

The work in England and Wales was under the general charge of Mr. H. B. Woodward, F.R.S., and was carried on in three districts, which are referred to as the Midland district, the Southern district and the South Wales district.

In Scotland the work was superintended by Dr. John Horne, F.R.S., and was of necessity somewhat more scattered. In the following report the results are grouped also under three districts: the West Highland district, including Skye; the Northern district; and the East Highland district.

The work in Ireland, which is limited to a re-survey of the drift-covered areas, was in charge of Mr. G. W. Lamplugh and was carried on in the neighbourhood of Dublin.

A few of the more important results will now be briefly indicated.

In the Midland district the detailed mapping on the six-inch scale has led to some modification of the earlier maps. The so-called Permian outlier west of Rushton has been proved to belong to the Lower Carboniferous series. The Triassic area which forms the greater portion of Sheet 110 is for the most part covered by glacial and fluvio-glacial deposits. Some interesting details as to the nature, distribution and probable mode of origin of these deposits will be found in the following pages.

6149 Wt. 1858. 500—8/02. Wy. & S. 376*r*.

Digitized by Google

Mr. Teall.

In the west of England the process of subdividing the great killas-formation of De la Beche has been continued, and a new division—the Hayle Sandstone—has been recognised. There is every reason to hope that as this important work proceeds the structure of the district will be made out and the true relations of the Devonian to the pre-Devonian rocks ascertained.

A considerable mass of granite, later in date than the main mass, has been found in the Land's End district, thus proving that the granitic area is not so simple in structure as is represented in the earlier maps. Special attention has been paid to the metamorphism produced by the granite, not only on account of its scientific interest, but also because the more important mineral veins occur in the metamorphic zone. Some isolated metamorphic areas, which indicate the proximity of granite to the present surface in districts where no granite is visible, have been met with. The work of recording the mining information has been delayed pending the appointment of an officer whose duty it will be to devote himself especially to this object. The appointment has now been made and the work will be proceeded with.

In the Devonian and Carboniferous areas of the west of England additional evidence has been obtained of an important unconformity between the Middle Culm or Wearde beds and the Devonian. The Lower Devonian succession has been worked out in a more satisfactory manner than heretofore.

The progress of the work of mapping the South Wales coal-field has necessitated the examination of the Lower Palæozoic rocks which come within the northern border of Sheet 230. The Ordovician and Silurian rocks which occur within the sheet have been examined, but no natural undisturbed junction has been met with. Evidence of faulting, probably accompanied by over-thrusting, has been found all along the line, and the dominant movements have been connected up with the disturbances of Cribarth and the Vale of Neath to which reference has been made in previous summaries.

Inliers of Silurian rocks, hitherto unsuspected, have been found in Gower, thus proving a great but, probably, local diminution in the thickness of the Old Red Sandstone. No definite separation of Upper and Lower Old Red Sandstone has yet been found possible. The sequence of red beds appears to be conformable throughout; but, on the other hand, there are signs of an unconformity between the Old Red Sandstone and the Silurian rocks.

The deep trough of Coal Measures extending from Swansea to Llanelly has been further examined and found to contain some of the highest measures of the coal-field. Two outliers of Trias have been proved to occur in Gower.

The transportation of glacial drift which has taken place in a general south-westerly direction in the districts previously examined, has had a southerly impulse given to it across the northern and western portion of the Carboniferous area, from which the presence of a great body of ice in Central Wales may be inferred.

Digitized by Google

Mr. Teall.

In the northern district of Scotland, work has been carried on in Ross-shire and Inverness-shire, extending eastwards from Loch Hourn and Loch Ailsh. Much additional information has been obtained as to the crystalline schists and the associated igneous rocks. The Glenelg plutonic complex has been found to consist of acid, intermediate, basic and ultra-basic rocks which have been intruded into the Moine-schists. The more acid members of the series have been sheared and granulitised in certain places by later movements, and dykes of quartz-felsite, porphyrite and mica-trap traverse the complex.

In the Alness district of Ross-shire, a bluish grey mica-schist belonging to the Moine series has been traced into a banded hornfels which forms a contact zone round augen-gneiss. From this it has been inferred that the contact metamorphism was anterior to the movement which produced the foliation in the Moine series. Lenticular sills of hornblendite and two small exposures of the rare and interesting rock known as scyelite have been observed in the same district.

In the West-Highland area, dykes of a dioritic rock precisely resembling the malchites of the Odenwald, have been met with near the head of Loch Eil. They traverse muscovite-biotitite-gneiss, amphibolite and pegmatites, but are also cut by thin strings of pegmatite.

In the central district of Scotland, the examination of an area between Pitlochry and Blair Athol has brought to light important evidence bearing on the sequence of the Highland-schists in that area. The graphite schist, which is in many places separated from a mass of black schist by folded quartzite, has been traced continuously round the folds into the black schist, and the identity of the two in that area has, therefore, been established. The quartzite appears to be the highest member of the series, and there is some evidence of an unconformity at its base. Interesting evidence bearing on the age of the newer granite has been obtained. In the Alness district of Ross-shire the basal conglomerate of the Old Red Sandstone contains fragments of these granites, whereas in the region north of Clachlet in Argyllshire, the volcanic series, which is presumably of Lower Old Red Sandstone age, has been pierced by granite. It is not improbable that many of the newer granite masses belong to some portion of the Old Red Sandstone period which is known to have been a period of granitic intrusions in other portions of the British Isles.

The work in the Skye district has led to the recognition of Cretaceous rocks in Soay Sound and Scalpay. The zone of *Pecten asper* has been definitely identified in the latter island, and evidence of the great Upper Cretaceous transgression has thus been found where it had not been hitherto suspected.

An interesting series of composite dykes of Tertiary age has been found in the Lorne Plateau. Some of these have been filled at three successive periods; the earliest intrusion being olivine-dolerite and the latest quartz-felsite. Along one of these composite dykes a series of neck-shaped masses composed of agglomerates and lavas has been mapped.

Digitized by Google

Mr. Teall. The detailed mapping of the drifts in Ireland was commenced in the Dublin area. A large portion of this area is deeply covered with drift which, therefore, has a much greater influence on the nature of the surface than the solid geology.

The general composition and distribution of the drifts, the manner in which they have modified the pre-glacial topography in the lower portion of the area, and have, in turn, been modified by this topography in the higher ground, as well as their influence in determining the character of the soil, are briefly summarised in the following pages.

Among the points of interest arising out of last season's work are two which deserve special mention. The esker-like ridge, south of the Liffey, has been found at one point to rest on a water-worn floor of Carboniferous Limestone. At the same locality the gravels of the ridge can be seen to pass laterally into gravelly clay, full of scratched stones, resting on a striated rock surface. These facts strongly support the widely accepted view that ridges of this type are the casts of sub-glacial water-channels.

The examination of the northern slopes of the Dublin Mountains, included within Sheet 112, has led to the conclusion that the short, deep, water-cut gorges, which occur as notches on many of the projecting spurs, like similar gorges recently described in other regions, have been excavated by powerful streams, either draining directly across ice or representing the overflow from lakes held in between the hills on the one side and the margin of the ice-sheet on the other.

I.—ENGLAND AND WALES.

I.—FIELD-WORK.

Mr. Woodward. The ground to be surveyed was arranged in three areas under the District Geologists as follows:—

1. Midland district under Mr. C. Fox-Strangways.
2. Southern district under Mr. Clement Reid, F.R.S.
3. South Wales district under Mr. A. Strahan.

In the Midland area the surveys of Sheet 110 (Macclesfield) and of 141 (Derby and Loughborough), together with that of the Cheadle coal-field in Sheet 124, have been finished. The Memoir in Explanation of Sheet 156 (Leicester) has been completed, while those in explanation of Sheets 110 and 141 and district memoirs on the North Staffordshire coal-field, including that of Cheadle, and on the Leicestershire coal-field are in preparation.

In the Southern area, Sheet 351 (Penzance) has been completed with the exception of the mining information. The Memoir in Explanation of Sheet 314 (Ringwood) was finished, and this, as well as memoirs dealing with the geology of Exeter and Southampton, would have been published, but that questions

Digitized by Google

concerning a uniform price for memoirs have caused delay. The Memoirs on Sheets 298 (Salisbury), 317 (Chichester and Midhurst), 350 (Torquay), and 355 and 356 (Kingsbridge and Start Point) are in hand. Mr. Woodward.

In the South Wales area the survey of Sheet 247 (Swansea) has been completed, but some colliery information has yet to be obtained. The Memoir in Explanation of Sheet 263 (Cardiff) was finished, and other memoirs on Sheets 231 (Merthyr Tydvil), 248 (Pontypridd), and 262 (Bridgend) are in hand.

Proofs of the general memoir on the *Cretaceous Rocks of Britain*, vol. ii., by Mr. Jukes-Browne, and of that on the *Geology of the Isle of Man*, by Mr. Lamplugh, are still in hand. A memoir on the *Water Supply of Berkshire* has been completed, and we are indebted to Mr. H. W. Monckton for editing the MSS. left by the late Mr. J. H. Blake on the geology of the country around Reading in explanation of Sheet 268. The publications during the year are noted on page 94.

In addition to the ordinary field-work, special examinations have been made of new railway cuttings; those from Axminster to Lyme Regis, and from Alderton to Wootton Bassett (on the South Wales Direct Railway) were noted by myself, and the sections exposed by the Goole and Marshland Railway were recorded by Mr. Gibson.

Through the courtesy of Mr. James Mansergh, F.R.S., then President of the Institution of Civil Engineers, Mr. T. C. Cantrill had the opportunity of examining the sections along the course of the aqueduct of the Birmingham Corporation Waterworks from Rhayader to Frankley; and by kind permission of Mr. A. McDonald Cobban, Mr. Gibson was enabled to examine a series of cores from a deep boring at Scunthorpe in Lincolnshire.

1. Midland District.—Cheshire, Staffordshire, and Derbyshire.

Mr. C. Fox-Strangways, District Geologist.
Mr. W. Gibson
Mr. T. I. Pocock
Mr. C. B. Wedd
Mr. J. Allen Howe
} Geologists.

Lower Carboniferous Rocks (Cheshire and Staffordshire).

These rocks occupy the eastern side of Sheet 110. They are arranged in a series of synclinal and anticlinal folds running in a more or less northerly direction. The northern part of this region has been mapped by Mr. Pocock, and was described in the last *Summary of Progress*; the southern portion has been mainly surveyed by Mr. Wedd, with the exception of the ground north of Rushton Spencer, which has been done by Mr. Howe. Mr. Fox-Strangways.

Digitized by Google

Mr. Wedd. The Lower Carboniferous shales and sandstones in this area rise into a well-marked anticline running N. and S. by Lask Edge, High Bent, and Brown Edge. The structure is well shown by the change of dip in the shales and grits in Dingle Brook, which flows round the north end of the ridge; and in the cloughs between Cloud Hill and Rushton, where the anticline appears to be pitching down or dying out northwards. This fold is succeeded on the east by a shallow syncline running approximately N.N.W. on the west side of Rudyard Reservoir, as is well shown by the ridges of the Third and Fourth Grits. East of the reservoir another syncline runs in the same direction between Rudyard and Heaton, the outcropping edges of the Fourth Grit illustrating the structure. Both these synclines appear to be dying out northwards. Between them the relatively narrow valley of the Rudyard Reservoir may be assumed to be occupied by an anticline, perhaps in part cut out by a fault running along the valley. East of the Rudyard-Heaton syncline another anticline running W. of N. brings up the so-called "Yoredale Sandstones" again along the edge of the map.

The folding of the hard Millstone Grits intercalated with soft shales is accompanied by a certain amount of local faulting. A fault with northerly downthrow runs E.N.E. across the Horton syncline through Raecliff Wood, where it displaces the Third Grit; it also probably throws the Third against the Fourth Grit on the east side of the reservoir. A short distance further north there is a similar fault with the same downthrow. Just north of Hollins an E. and W. fault with northerly downthrow crosses the anticline of Lask Edge and is continued on into the Biddulph Valley. The purple grit of Rushton appears to be cut off on the south and thrown against shales by a N.W. fault passing south of the Crown Inn. A N.W. fault passing under Wellbeach House west of Rushton Station seems to throw down the Bunter on the east against Lower Carboniferous, and the eastern boundary of the Bunter is considered by Mr. Wedd to be probably also faulted.

On the top and along the flanks of the anticlinal ridge extending by Lask Edge, High Bent, and Brown Edge, red, purple, and white sandstones are exposed, which are upwards of 20 feet in thickness. These beds are indicated on the old survey map as "Yoredale Sandstones." The same series of sandstones and shales comes to the surface east of the Rudyard syncline. In one of the highest sandstones in this series near Dingle Brook, on the west side of the western anticline, there is a two-inch band of hard grit crowded with casts of small lamellibranchs (*Posidoniella*?). This band is separated by thin black shales from a higher bed of grit with plant remains. Above this there is a thick series of black shales with hard sandstones and layers of calcareous bullions containing *Goniatites* in abundance; these are well seen in Dingle Brook; and in Lee Wood, Rushton. The shales are succeeded by several grits of the Millstone Grit series, which are more numerous and thicker than in the Biddulph valley. Commencing at the north the lowest grit is seen at Heaton and Fairboroughs. It consists of lavender or grey, flaggy, micaceous

Digitized by Google

grit with intercalated beds of purple shale, resting on very massive, hard, grey grit, with occasional pebbles. This grit appears to be the so-called "Permian" of the old survey. Though similar in colour to the lavender sandstones of the Keele series of the Upper Coal measures, it is a sharper, harder, and more quartzose grit, weathering to red sand rather than to crimson marl. Though it clearly overlies black shale, Mr. Wedd has not been able to find any section showing its relation to higher beds; but at the same time it conforms markedly in strike and dip to the folding of the Lower Carboniferous shales. The grit, shown on the old map as a small isolated patch of "Permian," some little distance west of Rushton, is clearly a ridge of grit overlying black shales and dipping N.W. in strict unison with the folding of the Lower Carboniferous of the locality, to which it clearly belongs. The general strike of the beds about Leo and Rushton also shows that these so-called Permian beds belong to the Lower Carboniferous series. Near the Inn, a red and purple grit with white blotches, shown on the old map as Bunter, is on the same strike as these beds, and undoubtedly of the same age. Mr. Wedd.

The shallow syncline of Horton, which appears to be diminishing or dying out northwards, will in its northerly continuation occupy the ground between the main anticline of Rushton and the syncline of Heaton, against which latter it is probably faulted, the intervening anticline being mainly cut out. Consequently it may be expected that the beds here will be wrinkled into but slight folds, or will be nearly flat, so that a bed occurring at the surface would remain at or close to the surface for a considerable distance.

A short distance S.S.E. of Rushton Church, lavender grit, similar to that described above, is seen, and it is probably identical with the lowest grit of Heaton (the Fifth Grit). Above this the Fourth Grit bends round with the syncline, and is exposed at Heaton. It is a thick, massive, pink and white, rather coarse-grained grit with seams of small pebbles. This grit re-appears on the west side of the Rudyard Reservoir below the Third Grit in Raecliff Wood, and is repeated by a fault. It bends round in another syncline, and runs south of Horton, where it forms a strong ridge below the Third Grit. Some distance further N.W., below Cloud Hill, two or three thin beds of grit which are close together occupy the same relative position below the Third Grit. These are doubtless the attenuated representatives of the Fourth Grit of Heaton and Horton. On the west side of the Biddulph valley no trace of this grit is seen, so it has doubtless died out.

The highest grit seen in this area is a massive, compact, rather coarse-grained false-bedded red and white grit, with seams of pebbles. It rises in a ridge above the Fourth Grit, and runs from Rudyard Reservoir N.N.E., passing east of Hunt House. On the west side of the reservoir the same grit bends round in a syncline and occupies the high ground of Harpers Gate and Grindlestone Edge.

Digitized by Google

TRIASSIC (STAFFORDSHIRE AND CHESHIRE).

Mr. Wedd and Mr. Howe.

Bunter.—A small patch of Bunter comes into the ground under consideration to the north of Rushton, but the area occupied by the rock is not so extensive as indicated on the old survey map. Mr Wedd finds that it consists of the usual red and mottled sandstone with more or less abundant pebbles. It seems to be brought against the Lower Carboniferous on the west by a fault running N.W. under Welbeach House. It is probably bounded on its eastern side also by a fault. In the river banks above Hug Bridge there is an interesting exposure of these beds which has been mapped by Mr Howe. The upper 20 or 30 feet of these, well seen in Red Pool, consists of soft red sandstone with small pebbles and lenticular patches of red marl of varying size; they pass down gradually into a more marly group, shown in the river bank 200 yards east of Hug Bridge. These red marls, which are described in the memoir on *The Geology of the Country round Stockport, Macclesfield, Congleton and Leek*, p. 36, as of Permian age, are now considered to be the lowermost of the visible Bunter beds; they contain numerous bands and lenticular patches of bleached sandy marl. It is the similarity of these markings to those of the Permian of Manchester that seems to have led previous observers to place these beds in the Permian.

Keuper.—In the western part of the map Mr Gibson has found that the Keuper marl is only exposed on the banks of the River Dane, and in the stream near Belchow House. Messrs. Wedd and Howe also report exposures of Keuper marl along the Wheelock and Weaver with the tributaries the Croco and Wade Brook, and in the deep cloughs north of Congleton. It consists principally of red marl with thin beds of gypsum, and a few thin red and white flags at intervals. The beds are much disturbed and sometimes sharply folded, but there is a general westerly dip.

TRIASSIC AND LIASSIC (DERBYSHIRE).

Mr. Fox-Strangways.

The revision of the country to the south of Derby in the northern part of the one-inch Map 141 has shown that the only solid strata that come to the surface are the Keuper marl, and two small outliers of Lias and Rhætic beds. The Keuper marl forms rising ground between the Trent and Derwent, as well as to the north of the latter river, and to the east of the Soar. There is, however, very little of interest to note in this formation. It consists of the usual red marls; but in the neighbourhood of Derby it becomes more sandy, although there are no special beds of sandstone that can be separated out, as has been done on the south side of the Trent. Just beyond the northern edge of the map these sandstone beds appear to become rather stronger, and it is probable that they will be able to be traced in that country. At Chellaston, and to the east of the Soar at Thrumpton, Kingston, and Gotham, the Keuper marl contains an important bed of gypsum, which is worked at these places. It varies in thickness,

Digitized by Google

the average being about 6 feet, but occasionally it is said to be much thicker. Although the gypsum usually dissolves when near the surface, its outcrop can be traced with considerable accuracy for some miles. Mr. Fox-Strangways.

In the neighbourhood of Gotham there are two conspicuous outliers of Lower Lias and Rhætic beds, which constitute the extreme N.W. outcrop of these beds in this district. The dark Rhætic shales have been seen at a few places; and, from the outcrop always occurring on a steep escarpment, is not difficult to trace.

The lowest beds of the Lias form a nearly level surface on the summit of these hills, and the limestone has been quarried at several places, but the beds are not thick enough to be of much commercial value.

PLEISTOCENE (DERBYSHIRE).

In the south-eastern portion of the county there is very little true glacial drift; but the post-glacial beds are very extensive, and of considerable interest. The separation between the two is not easy to define, as will be seen presently.

The principal deposit of Boulder-clay occurs at Chellaston, which is situated at the end of the ridge separating the valley of the Trent from that of the Derwent. It occupies eroded hollows in the marl, and consists of two separate deposits, the included fragments being derived from the north and west in the lower clay, and from the east in the upper. The other patches of Boulder-clay are of no great thickness, and occur along the ridge between Mickleover and Derby; in the low ground south of Derby, and along the rising ground north of Barrow-upon-Trent. A good deal of coarse gravel occurs along the ridge by Mickleover, Littleover, and Derby, but it is not easy to separate it from the general mass of drift. There is also a scattering of pebbles over nearly the whole of the ground; the importance of which, in the absence of sections, it is difficult to estimate. The most important beds are, however, the post-glacial deposits of the Trent and Derwent valleys, which have been ably described by Mr Deeley.* Although Mr Deeley's sub-divisions are in the main correct, it is not easy to follow his correlation of the different beds. There are gravels of three or more periods in these valleys, which more or less resemble ordinary river gravels, and Mr. Fox-Strangways cannot find any evidence that these are "interglacial." The highest gravels may be of late glacial age, having been laid down when glacial conditions still existed in the neighbourhood, but there is no true Boulder-clay over them. They, in fact, form a connecting link between glacial and post-glacial times. The highest of these terraces is about 50 feet or more above the present river flat; and although generally forming a fairly level plain they, in some cases, gradually rise on the inner side quite another 50 feet or more. It is here that they become difficult to separate from glacial beds, and we propose therefore to call them "high level valley gravel."

* *Quart. Journ. Geol. Soc.*, vols. xlii., p. 437, and lii., p. 497.

Digitized by Google

Mr. Fox-Strangways.

The principal terrace is from 15 to 20 feet above the modern alluvium, against which it usually terminates in a well-defined bank. On the south side of the Derwent this terrace has a breadth of a mile and a half, and at Allenton contains the remains of *Hippopotamus*.* Below this are other terraces, which merge into the alluvium of the present rivers; so that, although they end off in a steep bank on the higher side, they usually tail off down stream, and cannot be separated from each other.

There are two interesting deposits of lacustrine clay occupying old hollows in the Keuper marl; one of these, Sinfin Moor, has an area of about 2 square miles†; and the other, Gotham Moor, is probably double this size, but the mapping of the latter is not yet completed. The deposit of this latter place is a white marl with much vegetable matter, but the specimens yet obtained are too decayed to be determinable. In the Erewash Valley close to Toton Sidings a stiff marly clay with shells occurs beneath the present alluvium of the stream, in which Mr. Clement Reid notes the following species—

Limnæa (*peregra ?*).
Valvata piscinalis.
Bithynia tentaculata.
Chrysalis cases (several species).
Daphnia (winter eggs).
Lycopod (spores).
Scirpus lacustris.

The Trent alluvium shows a great number of old river courses, one of which is of historical interest as being mentioned by Shakespere‡; it is close to the village of Repton, and has a length of about 2 miles.

GLACIAL (CHESHIRE).

Mr. Gibson.

The drift occurring in this district consists of two main types —the older Boulder-clay or true till; and the later fluvio-glacial deposits with which we have principally to deal. As the former of these has been seen at very few places there is little to be said about it. The fluvio-glacial deposits however cover the greater part of the district; and, starting from a level plain of about 150 feet at Crewe and Middlewich, gradually rise about Congleton and Macclesfield, till in the hills beyond they attain an altitude of about 800 feet.

The western part of the district is best described under two divisions—the general flat of Crewe, Sandbach and the country to the north; and the ground bordering the Dane river, which intersects this plain. Mr. Gibson finds that sections are not numerous except in and around the Dane valley; where, however, the sands and clays appear to be of a different origin from those around Sandbach.

---

* H.H. Arnold Bemrose. *loc. cit.* p. 497.
† Mr. Deeley gives a section of the Sinfin Moor deposits. *loc. cit.* p. 502.
‡ *Henry IV.*, Pt. I., Act iii., Sc. 1.

Digitized by Google

The sands and clays of the general plain are apparently unstratified, and of very varying thickness, being only a few feet thick at Wheelock and Betchton, and over 70 feet around Sandbach. The relation between the sand and clay is not determinable, but as a rule clay overlies an irregular surface of sand, which is itself deposited on an irregular floor of Keuper marl. A few glaciated boulders occur in the clay, but the sands are remarkably free of pebbles of any kind. The sands attain their maximum thickness at Sandbach, but thin out rapidly on approaching the Weaver valley to the west, or the Dane valley to the north. Mr. Gibson.

Around Crewe, and for some distance to the west, there is a finely laminated clay, but its relation to the beds further north is uncertain. A boring in the town proved 30 feet of sand overlying 150 feet of clay.

In the valley of the Dane south of Cranage Hall, and at the Viaduct, beds of Boulder-clay are seen which are the oldest glacial deposits of the district. They are about 30 feet thick, and consist of stiff, brown clay full of striated stones with numerous fragments of *Turritella* and *Cardium edule*. This till is overlaid by a fine, brown, laminated clay which is seen in a brickpit south of Cotton Hall, and appears occasionally to occupy the lower part of the banks of the Dane and other streams. It is overlaid by a light-coloured stratified sand, which spreads out over the surface of the surrounding plain.

Nearer Congleton Mr. Wedd observes that the drift seen in the cliff-sections of the Dane is only a few feet thick, but away from the Dane the thickness is considerably greater. A well on the west side of Eaton Park showed a thickness of 63 feet without reaching the Keuper marl. It is of the usual character; but, besides the common type of current-bedded sand and gravel, sometimes containing shell fragments, there is a somewhat different deposit of yellow sand occupying flat-bottomed valleys (in many cases flanked by normal moundy drift) or level plains. This sand is entirely free from gravel, and probably has a different origin from that of the ordinary glacial drift. It seems to have been reconstructed out of drift material during the earliest stages of the Dane drainage system. These flat sands are sometimes seen to rest upon Boulder-clay. In the ordinary moundy glacial drift the boulders are much the same as those described in previous reports, Ennerdale granophyre, Eskdale granite, and various types of the Lake District Volcanic series being abundant. Small boulders of crinoidal Carboniferous Limestone are sometimes found, and grey flints occur sparingly. Mr. Wedd and Mr. Howe.

In the country north of the Dane Mr. Howe finds the same general succession. The greater part of the area is occupied, at the surface, by stiff, brownish, finely laminated clay; the remaining portion is covered by clean yellow sand. About Peover Superior, Allostock, and north of Goostrey a sheet of sand rests persistently on the laminated clay; but about Nether Peover the relation of the two deposits becomes obscure. Along the Crow Brook this order is reversed, and a clay reposes on sand. Some

Digitized by Google

Mr. Wedd and Mr. Howe.

of the ground mapped as clay consists of good stiff clay, which is so full of small lenticles of clean sand, that after cultivation the soil assumes quite a sandy aspect. Occasionally these lenticles swell out into rounded hills of sand.

The relation of the Dane valley deposits to those of the rest of the plain has not been made out, from the fact that they are never seen together in any one section, and their outcrop is always a feather edge. It is probable however, that they are more recent, and fill in an old line of drainage across the plain.

As we approach the hills the drift becomes much thinner and very irregular in its distribution. Mr. Wedd finds that the Millstone Grit ridges and the porous Bunter sandstone are generally bare of drift. Both clay and sand lie on the high ground within the syncline of the Fourth Grit south of Heaton, but it is doubtful whether there is any in a similar position within the syncline of the Third Grit of Harper's Gate and Grindlestone Edge. The drift of this tract is on the whole similar in composition to that of the plain, and consists of red and brown stony and often sandy clay, with patches of sand and gravel. Amongst the boulders there is naturally a greater proportion of local Carboniferous material, principally fragments of the Millstone Grit and lower sandstones. Boulders of Carboniferous Limestone also occur, and, in the neighbourhood of Heaton and Rudyard, Bunter pebbles are abundant. No shell fragments have been found in this tract, though they occur in the Biddulph valley. The drift, filling the valleys between the anticlinal and synclinal grit ridges, is for the most part flat or gently sloping with few definite mounds; but at Rushton, about the mouth of the Rudyard valley, it is moundy.

Mr. Pocock.

In the district west of Macclesfield Mr. Pocock observes that the drift, which occurs at the surface over the greater part of the low country, belongs to a stage of the glacial period when the *mer de glace* had retreated from the Pennine Hills, and wide sheets of water stretched along the plain at their foot. The rivers Bollin and Dean, emerging from the upland valleys, coalesced on the lowland, and deposited their silts and gravels in terraces along the flanks of the hills. Some account of one of these terraces, which occurs at about the 500-feet contour, was given in last year's report, where it was stated that the shoreline was situated near a ridge of the Triassic formation which abuts against the Carboniferous rocks three miles south of Macclesfield. But there are indications that the water had previously stood at a higher level, and overflowed the Triassic ridge into the basin of the Dane. A thick deposit of chocolate-coloured brick-clay is found at a level of about 570 feet on the east side of Macclesfield, similar in character to the stratified clay at the 500-foot level. A good section may be seen at a brick pit on the Buxton Road near the canal bridge, where the clay is overlaid by gravel and sand, which formed an ancient delta laid down by a stream emerging from the adjacent valley. Brick-clay at a corresponding level occurs on the west bank of the Bollin near Broken Cross, the inter-

Digitized by Google

vening valley being cut down to a depth of about 140 feet. Mr. Pocock.
Although this clay is in some places 40 feet thick, few remnants of it have survived denudation. It was probably of wide extent, and the water in which it was deposited was high enough to overflow the watershed in the Churnet Valley, and connect with the eastern drainage system of England. West of Broken Cross the clay seems to become more stony, which probably indicates that it was formed in a lake between the ice sheet and the Pennine Hills. After the retreat of the waters below the 500-foot level, the river Bollin formed a succession of terraces, on part of which the town of Macclesfield is built. A short distance farther north the river flows outside our area, and its subsequent geological history has not been worked out. After the retreat of the waters below the 500-foot level, the gravel which formed the margin of the lake at the mouth of the Langley valley gave rise to a small brook which flows through Dane's Moss and eventually escapes into the valley of the Dane. Hence the water-parting between the Bollin and the Dane since the glacial period has passed through an old gravel deposited by the former stream. This is a phenomenon frequently exhibited by the small streams in the western part of the area.

The remainder of the drift to be described lies within the drainage basin of the Dane, to the south and west of the Triassic axis before mentioned. The ground level falls gradually from a height of 500 or 600 feet between Alderley and Gawsworth to about 250 feet at Chelford and Withington, and the configuration of these two districts is strongly contrasted. Much of the ground in the former area presents on a small scale the familiar features of hills of circumdenudation and valleys of erosion, which are characteristic of land sculpture among horizontal strata that have been subjected to prolonged denudation; the latter consist of horizontal expanses of clay and sand but little broken, save where the larger streams have cut their channels across them. But the passage from the one type to the other is gradual.

The higher parts of the drift from about 450 feet to 600 feet consist of ridges of sand and gravel, which may be nearly 100 feet thick, with occasional hummocks of clay apparently rising from beneath them. The nature of these deposits is not very clear, partly on account of their denuded condition, and partly from the lack of any good sections.

The group of sand mounds in the parishes of Henbury and Gawsworth may have been formed by the flood waters liberated from the ice sheet, as it retreated further and further from the high ground, while the clay hummocks may be *moraine profonde* formed while it was still in motion on the plain.

At a somewhat lower level the character of the drift becomes more apparent, and phenomena are presented similar to those described in the basin of the Bollin, but on a smaller scale, and of a later geological time. Platforms of clay at successive levels may be traced for considerable distances across the country, the higher ones small and broken, the lower of greater extent.

Digitized by Google

Mr. Pocock. As they are followed into the higher ground, these clays disappear between beds of sand and gravel, or are laid against higher platforms. Towards the plain they are cut off by denudation and split up into outliers. These clays are of a chocolate brown colour, rather sandy, and free from pebbles. They are not so conspicuously laminated as some of the clays of the Bollin basin, but they are usually interbedded with sand, and can be followed for considerable distances at a nearly uniform level. They are not more than 20 feet thick, and sometimes much less, especially on their inner margins. Owing to extensive denudation they occupy small areas, though sometimes they exceed in thickness the clays which cover large tracts of the lower ground further west.

A good section of these clays can be seen at Buck's Hill, between Siddington and Thornycroft Park. This is a small round hillock about 300 yards in diameter, the top of which is 410 feet above the sea. A pit on one side shows a bed of sandy brown clay free from stones, about 15 feet thick, resting upon sand. The summit is a rather coarse gravel composed of erratic pebbles resting on an eroded surface of the clay. This is an outlier of a clay bed which, with its overlying gravel, can be traced at nearly the same level all across the area from Henbury to Marton. Between Marton and Gawsworth the gravel forms an extensive terrace.

This and other terraces at various elevations are clearly water levels of Glacial age and may have been formed in somewhat the same fashion as those described by Prof. J. Geikie in the Clyde basin (*Great Ice Age*, p. 175); *viz.*, in a lake bounded by ice on one side and by rising ground on the other. But there is no certain trace of ice action in the clays, and so far as the evidence goes they might have been laid down in a lake which covered the greater part of the Cheshire plain, the successive terraces being different stages in the retreat of the waters. The various little streams which intersect the drift in this part of the area usually have remnants of sand and gravel terraces along their banks, which can be traced down their courses and connect with the lake terraces on the more open ground. These streams take their rise in the more elevated part of the drift, so that the terraces connected with them must be of later date than those formed by the Bollin. A succession of them may be seen on the sloping grounds east of Capesthorne Park, the lowest of which claims particular notice, as it is the connecting link between the more hilly drift just described, and the flatter drift to the west. Beginning as a narrow strip of sand raised above the stream which flows through Capesthorne Park, this terrace rapidly opens out westwards, and covers many square miles in the townships of Chelford, Withington and Kermincham. It consists of fine reddish sand of variable thickness, but generally not more than 8 or 10 feet. Eastwards, it protrudes long tongues up the little valleys near Alderley Park and Siddington, becoming more gravelly and rising in level, as it is traced up stream. Westwards, it is gradually replaced by a clay of about the same

Digitized by Google

thickness, which covers the greater part of the ground between Peover and Goostrey, and passes into the area mapped by Mr. Howe. Mr. Pocock.

Sections of the clay can be seen near Kermincham Lodge and Withington Green. It is a dense brown clay with faint traces of lamination, and containing a few striated boulders. Though it is no thicker than some of the clays in the hilly drift, it covers a far wider surface, and is comparatively little denuded. In some places it passes almost imperceptibly into sand. Elsewhere, as in the Peover Brook, near Withington Park, it may be seen with sand beds above and below. Water seems to have been the principal agent in its formation, but the Northern erratics, which it contains, show that there was an ice-front near enough to send its ice floes across the lake, and drop its stony *débris* over the muddy bottom.

The drifts of the whole area now described present a continuous story of denudation and redistribution of sediment at successively lower levels, the later stages of which were undoubtedly accompanied by glacial action, and the whole of them are subsequent to the retreat of the ice from the Pennine Hills. But whether the ice disappeared and a temperate climate supervened in the interval, the evidence collected in this area alone does not suffice to determine. That the interval was a long one may be inferred from the amount of denudation which took place. Before the deposition of the flat drifts in the west, the tiny brooks in the hilly drift cut deeper gorges, and removed more sediment than the larger streams have since accomplished in the lower ground.

RECENT DEPOSITS (CHESHIRE).

Along the Dane valley river-terraces are well developed. In the plain they are often made of sand and loam, and less frequently gravel; but on the higher ground of Bosley they are invariably composed of gravel, which is usually rather coarse, and merges gradually into the surrounding drift. These terraces occur at varying heights. Sometimes they constitute the present banks of the river, or else they lie some distance above the present river course, and rest on ledges on the steep walls of the valley. At Somerford Park a coarse river gravel lies on the edge of the plateau, fifty feet above the present alluvium. East of Eaton Hall the highest terrace on the west side of the river can be traced for a great distance; it is unusually broad, and consists of sand and silt. The different terraces show unmistakably the formation of the present valley, which is proved to be newer than the laminated clays. Mr. Howe. Mr. Wedd.

Alluvial terraces are beautifully developed along the entire course of the Dane. They are so little liable to flooding, that they are cultivated in places where the banks are high. Nearly all the streams have narrow fringes of alluvium, while many of the shallow depressions in the drift have their bottoms filled with like material.

Digitized by Google

Mr. Gibson. Mr. Gibson observes the curious fact that these hollows and the tributary streamlets of the Dane and Wheelock rivers, converge towards the salt-bearing regions of Middlewich and Wheelock; showing that, unless the phenomena are accidental, the brine pumping has not initiated, but only assisted, the surface sinking.

Peat has accumulated in the hollows formed in both clay and sand, and has given rise to extensive mosses. Some of these still exist, but in many, notably Warmingham Moss, the peat has been completely cleared off.

ECONOMIC GEOLOGY.

Mr. Gibson. In the Cheshire district the absence of good road-metal is a serious inconvenience. The main roads are repaired with material brought from Penmaenmawr, while for second-class roads the Crowstones of the Lower Carboniferous series to the east are frequently used.

The drift clays are extensively used for brickmaking, round Crewe, and to the north of Congleton, and to some extent round Sandbach and Holmes Chapel. The sands yield building sand.

Taken generally the clays are devoted to pasture, the sands to tillage. Crops in the sand area, suffer more from drought than those composed of clay. In the latter, the numerous ponds, chiefly of artificial origin, are of much service, for though shallow, few dry up, and many show only a small diminution in the volume of water. In a few instances, where a thin capping of clay overlies sand, the crops suffer little, as the clay prevents evaporation.

The main water supply of the district is obtained from the sands. It is however insufficient, while the water is hard, and liable to contamination. Sandbach and Holmes Chapel obtain their supplies from this source, but Crewe town is supplied from the boring in the Trias near Whitmore Station.

In North Staffordshire the gritstones of the Third and Fourth Grits have been largely used for building, and for the stone fencing of the district. The Fifth Grit of Heaton has also been quarried; while the lower sandstones of Lask Edge and Brown Edge are used for road material. The black shales of the Lower Carboniferous, and the Boulder-clay on the west of Lask Edge are used for brickmaking. A water supply for local purposes is obtained from the drift-sand.

2. Southern District.—Devon and Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher, Mr. J. B. Hill, Mr. E. E. L. Dixon } Geologists.

ORDOVICIAN AND SILURIAN.

Mr. Reid. Though the year's work has not led to the discovery of palæontological evidence proving the Silurian age of any of the

Digitized by Google

killas in West Cornwall, yet as the mapping advances the succession of the rocks becomes more clear, and the probability of the Silurian date of extensive tracts becomes greater. It will be remembered that in former *Summaries* Mr. J. B. Hill divided the older rocks into four series, the oldest of which has long been known to yield Ordovician fossils. Above these Veryan beds come in succession the Portscatho slates, the Falmouth slates, and the Mylor series. Another lithological division, which continues the upward succession northwards may now be added, and may be termed the Hayle sandstone. It consists of thin-bedded, coarse, more or less felspathic sandstone, alternating with fine-grained black slate or shale, which latter resembles in character the shales of the Mylor series below. These four divisions, lying above the Ordovician, are provisionally referred to the Silurian, and it is hoped that the work of the coming season may enable us to show definitely the relation of the highest member to the fossiliferous Devonian of North Cornwall. Mr. Reid.

As the geological structure of West Cornwall is very obscure, it will be necessary to refer in more detail to the evidence on which this order of succession is founded; for, at first sight, the new division appears to pass under, not over, the Mylor series, and that view was taken by De la Beche in 1839.* Before discussing this matter, however, reference may be made to the newly mapped Silurian areas which were examined during the past year. The most convenient mode of doing this will be to commence with the oldest rocks, which occur in the area east of Falmouth, and work westward and northward to the newest division which has yet been mapped on the north coast.

The examination of the Gorran Haven coast sections by Mr. J. B. Hill has proved the further north-easterly extension of the Veryan series as far as that locality. It is interesting to note that the pillow lavas of Mullion Island were found at Gorran Haven on a similar geological horizon associated with limestones and quartzite. Further, although these pillow lavas had not been previously observed at this locality, Mr. Howard Fox† had discovered radiolarian beds in their immediate neighbourhood, still further linking them with the Mullion Island rocks. Although the Gorran Haven rocks have suffered much mechanical deformation and are in part converted into crush conglomerates, their characteristic appearance in the field is still preserved, and their identity is still further confirmed by microscopic sections. Besides their occurrence in these two localities, pebbles of this rock are common in the miscroscopic slides of the conglomerate at Nare Point, intermediate between Mullion and Gorran. They occur, therefore, along a line nearly 30 miles in extent, and their occurrence amongst the fossiliferous rocks of Gorran suggests that their age may be Arenig, corresponding to the age of precisely similar rocks occurring at Ballantrae on the coast of Mr. Hill.

* *Report on the Geology of Cornwall, &c.*, p. 100.

† A paper on "The Radiolarian Cherts of Cornwall." *Trans. Royal Geol. Soc. Cornwall*, vol. xii., 1896.

Digitized by Google

Mr. Hill. Ayr, which Mr. Hill had the opportunity of examining in September. Their resemblance in these two areas, separated by a distance of 350 miles, is so remarkable that it is scarcely possible to distinguish them, whether we consider their mineralogical character, their unique appearance in the field, or the rocks with which they are immediately associated. The rocks of Mullion Island have mainly escaped metamorphism on account of the protection afforded by the massive rocks of the Lizard region, which have preserved them from the effects of the earth stresses from the south-east.

The Nare Point conglomerate which separates the Veryan and Portscatho series has been referred to by Mr. Hill, in a former report,* as the possible line of demarcation between the Upper and Lower Silurian. It contains fragments of pillow lava as well as of the quartzite; and as the boulders of the latter were in the condition of quartzite at the time of their deposition, the break indicated by this conglomerate probably represents a protracted interval. The conglomerate also contains foliated igneous rocks, some of which have certainly been derived from the Lizard area, so that we have in Cornwall at least two periods of metamorphism, one of which is prior to the formation of the conglomerate, and its included pebbles of pillow lava, and one later. Of the age of the former we have no evidence, except that it must be pre-Arenig, while the latter is posterior to the Culm measures.

The mapping has been restricted mainly to the Portscatho, Falmouth, and Mylor series, proving the further extension of these divisions, which are provisionally regarded as Silurian. The lithological characters of these divisions have been described in former reports. While folding is everywhere apparent, the bedding can usually be detected, as well as the cleavage. The hade of the cleavage is S.S.E., and it crosses the strike of the bedding somewhat obliquely. Judging from the data furnished by the country between Truro and Gerrans Bay, there are grounds for believing that the stresses which have folded and cleaved the slates proceeded from S.S.E. to N.N.W.

Mr. Reid. The Mylor slates have now been traced westward and northward to Land's End and St. Ives Bay. Over the greater part of this area they retain a very uniform character, except for the variations caused by contact metamorphism. They consist mainly of soft shales or slates, black or dark-coloured when broken across, but more or less silvery on the surface of the laminæ. In places they alternate with very fine-grained sandy silts, but thus far they have shown no indication of contemporaneous volcanic activity, though intruded sills of greenstone are not uncommon.

Throughout this area the strike of the axis of the sharp folds runs about N.E. and S.W.; but as the limbs of the folds are nearly parallel, and are vertical or have often a high southerly

* See *Summary of Progress* for 1899, p. 95, and *Trans. Royal Geol. Soc. Cornwall*, vol. xii., Part 6, 1901.

Digitized by Google

dip, it is not easy to make sure of the true succession. In order to ascertain which was top and which bottom in the Mylor slates, the junctions with the sheets of greenstone were examined; but it was found that in every case in which the relations could be made out the greenstones were true sills, with contact metamorphism above and below. As fossils are absent, the only other way of deciding the question lay in working out the geology in such a way as to distinguish the general structure from the sharp plication above alluded to. Mr. Reid.

The sills of greenstone round the Land's End granite give a valuable clue. They are so thick and massive that they have resisted the plication, though they are often much sheared and full of small thrust-planes. Everywhere these sills dip away from the granite at an angle which apparently does not differ greatly from the slope of the granite surface below. Further, in the neighbourhood of Penzance and Newlyn one thick sill (at least 80 feet through) caps a series of hills in such a way as to show that it, and the associated slates, though disturbed are not overturned. Next, various slight indications suggest that the thick sills on the north coast and the sill which caps the hill near St. Erth may be on nearly the same horizon, even if they are not parts of the same sheet isolated by denudation. If this evidence goes for anything, and the sills keep approximately to the same horizon in the Mylor slates, we are apparently dealing with a mass of slate of only moderate thickness, folded and constantly repeated in small anticlines and synclines, and having probably a slight general dip towards the north. This view seems to be borne out by the similarity of the killas at Penzance and St. Ives, and its striking uniformity over the wide area between Ludgvan and Gwinear.

On tracing the killas eastward from Carbis Bay along the coast, however, its character alters somewhat, and after passing a thin greenstone sill of different appearance, we come to lighter-coloured killas, sometimes banded with green, and containing a larger proportion of fine silty sand. A pit near the western edge of the West Cornwall Golf-links shows sheared, coarse-grained, soft, highly-felspathic sandstone, with few or no grains of quartz sand. These soft, felspathic beds have been taken as the top of the Mylor slates, though they might equally well have been considered as the base of the hard Hayle sandstones which come on immediately above. Unfortunately the cliff face, where the junction should be seen, is now smothered with dune sand, and nearer the Hayle River the cliff is entirely composed of alternations of sandstone and shale. The boundary strikes southward to Lelant, then crosses the river near Hayle—unfortunately not showing clearly in the low river-bank. Next it passes through the overgrown railway-cutting south of Hayle, one end of this cutting being in dark slate, the other in light-coloured shaley sandstone. Then, following the normal strike, the boundary passes under the valley deposits north-eastward to Phillack, a good section of the felspathic top of the Mylor slates being

Digitized by Google

Mr. Reid. visible in a new road-cutting at Bodriggy, between Hayle and Copperhouse. Excellent sections of the sandstone are seen in Black Cliff, and also in the old quarries and river-bluffs around Hayle Harbour. East of Phillack the boundary turns sharply northward, through the Towans to the coast, being readily traceable across the dunes by the mine-tips. East of Godrevy the Hayle sandstone reappears with the normal east-north-east strike, though much folded. No trace of igneous rocks, either contemporaneous or intrusive, has yet been found in the sandstone; and though careful search was made, no fossils could be discovered. Even the worm-tracks and borings, and the so-called fucoids, so often occurring in Palæozoic sandstones, appear to be absent.

The junction of the Mylor slate and the Hayle sandstone is described in some detail, for the curvature of the strike yields the best evidence for the true order of succession. The normal strike of west Cornwall is north-east and south-west, but the uplift caused by the intrusion of the granite of the Land's End has everywhere caused the killas and its interbedded sills to dip away from the granite mass. This uptilt, at right angles to the strike, must necessarily divert the strike at Lelant, where the influence of the granite begins to be felt, towards the north, if the Mylor slate underlies the Hayle sandstone; but it would be diverted towards the south if the Hayle sandstone were the older of the two. As a matter of fact the diversion of strike is to the north. North-east of Hayle there is another northward diversion of the strike, apparently unaccounted for by any granite intrusion. But here, also, the diversion seems to be caused by a granite intrusion; for Mr. Dixon has discovered between Gwinear and Gwithian a metamorphic area, which seems to point to a buried boss of granite not far below. No doubt the true junction of the Hayle and Mylor series should be drawn as a sharp zig-zag line; but not being able to trace these minute details inland, we can only follow the general strike, the variations of which bring out thus clearly the true succession.

The greenstone sills which form so marked a feature in the Mylor slates of west Cornwall, have now been mapped throughout the country west of Camborne. The rocks, however, vary so much in original lithological character, and the superimposed shearing and contact metamorphism have caused so great changes, that it seems advisable to defer any fuller description of these rocks for a future *Summary*, when the petrological work will be further advanced.

GRANITE.

Though the granites of west Cornwall, like those of Devon, are probably of late Carboniferous date, yet as those examined last season are everywhere in contact with the Mylor slates, it will be convenient at this point to deal with them and with the metamorphism they cause. Here, also, the petrological evidence

Digitized by Google

will be left for a future report, the field evidence only being mentioned in any detail. Mr. Reid.

The general character of the Land's End granite and the character of its intrusive junction with the killas are so well known that it is needless to repeat the description.* A few points of interest noticed in the course of the new survey are, however, worthy of remark. In the first place it has been found that the Land's End mass is not all of one age or type, but includes an area of about seven square miles of a fine-grained granite of later date, which extends from Gulval Downs nearly to Zennor on the north, and from Amalebrea to Carnaquidden on the west. This granite is so fine-grained that it is commonly known as "whetstone" or "sandstone." Its composition is very similar to that of the coarse granite into which it is intruded. It is a buff or grey biotite granite with small (half-inch) scattered crystals of orthoclase and rarer crystals of pinite of about the same size. Its boundary is everywhere sharply defined, but there is no section showing the actual junction of the two rocks, though at its northern limit at Beagleton Downs loose blocks on the moor show numerous veins of this fine granite penetrating coarse granite of the common Land's End type. The newer granite forms undulating land, surrounded by tors or carns of the coarser type, but itself neither forms carns nor weathers into large rounded masses like those which nearly everywhere encumber the ground outside its limits. It tends to weather into small angular blocks, which are easily removed and are more convenient for building. The farmers consider the land to be of better character, but it could not be ascertained clearly whether this was due to any difference in the composition of the soil or merely to the greater convenience for working where large boulders were absent.

Much of Penzance is built of this fine-grained rock, with dressing of the ordinary coarse granite. Thus far only the buff rock near the surface has been used to any extent, but below fifteen feet the Castle on Dinas quarry shows an excellent grey stone, which ought to be of considerable value.† The Gulval Downs rock, however, does not split in the same way as the older granite, and appears never to be used for lintels or gateposts, even close to the quarries. It is used locally for road metal, and is better than the coarse granite, but not equal to the greenstone.

The Land's End granite (as distinguished from the newer Gulval Downs granite) is remarkable for showing a distinct but irregular bedding structure, which seems to be approximately parallel to the granite surface where the granite passes beneath the killas. This bedding is very conspicuous on the weathered carns or in the cliffs. It is apparently due to the orientation of the large felspar crystals, which, during the movements of the molten rock, have tended to arrange themselves parallel to the surface past which they flowed. The structure cannot well be

* See *Summary of Progress* for 1899, p. 87.

† See also De la Beche, *Report*, pp. 161, 494.

Digitized by Google

Mr. Reid. illustrated by hand specimens, though very noticeable in the field, for it is only an orientation of most of the crystals in one direction, not of all of them.

A short distance from the margin, usually less than half a mile away, this bedding, instead of dipping at high angles, becomes almost horizontal, suggesting that the granite overhead had formerly possessed a nearly level roof of killas. On applying this test to parts of the cliff where no killas now fringes the granite, so many places were discovered where the high outward dip was strongly marked as to leave little doubt that the present coast line corresponds very nearly with the original limit of the Land's End granite.

If the granite originally formed so flat a dome, the question naturally arises, What is its contour where hidden by killas? This question cannot yet be satisfactorily answered; but enough has been learnt to show that it often plunges beneath the stratified rocks at an angle of about 45°, though in other cases the angle is only 15° or 20°. Corresponding with the steeper hade, we find a metamorphic aureole fully three-quarters of a mile wide; but where the killas and greenstone transgress over the granite, as at Tremethick, near Penzance, the aureole widens enormously. The boundary of the metamorphic area here instead of sweeping round the bay in the granite, cuts across, suggesting that the whole area around Penzance is underlaid by granite at no great depth.

A metamorphic aureole, three-quarters of a mile wide, with a dip of the granite at 45°, would give a thickness of the aureole, measured at right angles to the cooling surface, of nearly 2,800 feet, and a depth to the granite at the outer limit of metamorphism of 4,000 feet. We do not yet know, however, to what depth this dip of 45° is continued, though in the Levant Mine a dip of nearly that amount has been followed to 1,500 feet below the sea-level, with no sign of any flattening. There, unfortunately, the width of the aureole cannot be measured, as its outer margin is beneath the sea.

Mr. Hill. The aureole of metamorphism encircling the Carn Menelez granite has been studied by Mr. Hill so far as the unsatisfactory nature of the ground would permit. The alteration of the innermost zone, extending to 250 yards from the granite, is so marked that little difficulty was experienced in spite of the lack of good sections. Beyond that zone, however, the evidence of its extension is partial in character. The mineral alteration of the inner zone is more or less complete, Andalusite, Muscovite and Biotite being extensively developed. In the outer fringe the secondary micas are often difficult to distinguish from original constituents, while Andalusite is altogether absent, the hornfels, where it exists, being likewise confined to the inner zone, so that beyond that limit the occurrence of spotted slate is the sole evidence of contact metamorphism, and this is so partial in its distribution that the demarcation of the outer limit of alteration with any attempt at accuracy is impossible. With these "spots," tiny elongated needles, which may possibly be referred to Chiastolite, have been

Digitized by Google

observed a thousand yards distant from the granite. Speaking generally, the aureole of metamorphism is about half a geographical mile in width (1,000 yards), but at Penryn Creek the spotted slates form a loop, the outer margin of which is two miles from the nearest visible granite, notwithstanding that the loop is free from elvan dykes. Moreover, the great elvan region which abuts against the granite at Gwennap contains large areas of spotted slate, which, although the spotting is generally of a more minute character than is found bordering the granite mass, it is obviously impossible to differentiate from the other. Spotting has also been occasionally observed in the vicinity of isolated elvan dykes. For the reasons above stated, it will be apparent that an engraved line on the map, to mark the limit of contact alteration in this area, would present such an inaccurate interpretation of an important petrological problem that its omission would be less misleading than its insertion. Mr. Hill.

This question of the underground contour of the granite surface is an important one for the miner, for the occurrence of certain ores, especially tin, is known to be intimately connected with the proximity of the granite. It is interesting therefore to find, as already mentioned, that an isolated metamorphic area has been discovered north of Gwinear by Mr. Dixon, and another around Leedstown. These seem to connect the granite district of Land's End with that of Camborne; but as we have not yet sufficient data for calculating the thickness of the metamorphic aureole, measured at right-angles to the cooling granite surface, we are unable yet to calculate the depth of the granite in metamorphic areas in which no granite is seen. Besides this, the width of the aureole is not the same round the different granite masses; and this variation seems to be due not merely to variations in the hade of the granite surface, but to the different intensity of the metamorphism. The killas close to the Land's End granite, for instance, is intensely altered into knotted hornfels, and the least width of the aureole, measured at the surface, is over half a mile. The smaller mass of the Godolphin granite causes less alteration, and gives a least width of aureole of about a quarter this amount. In striking accordance with this difference, is the strongly developed chilled edge of the Godolphin granite, contrasted with the very slight chilling noticeable round the Land's End mass. It is hoped that further light may be thrown on this question when the numerous mine-plans have been examined and the relation of the ores to the granite surface has been more thoroughly worked out. Mr. Reid and Mr. Dixon.

The Carn Menelez granite, which extends from Penryn to Camborne, was partly described by Mr. Hill last year.* Further examination of the jointing, orientation of the crystals and grain in this granite, shows that over the district generally the orientation is so feeble that it would often escape observation if not specially sought for. Moreover, although there is a general uniformity in the direction of orientation it is by no means constant, Mr. Hill.

* *Summary of Progress* for 1900, p. 107.

Digitized by Google

Mr. Hill. and if examination were confined to a limited number of sections the results obtained might be misleading. At Kennal Vale, however, these phenomena are carried a step further, and the parallelism is so marked that it could not fail to be detected by the most cursory examination. It approaches a definite structure, so much so that the orientation is no longer the feeble approach to crystalline arrangement confined to the attempt at parallelism of a sufficient number of the elongated minerals to ensure a grain; but there are definite visible planes set up in the rock which dip steeply towards the margin of the granite, while the rock in places is so foliated that its schistose character can be detected in a hand specimen. The foliation of the granite at Kennal Vale agrees in its trend and general hade with the corresponding planes in the slates which flank its margin.

Following the granite boundary 1½ miles further in a S.S.E. direction, we find at Treluswell, near Penryn, two foliated granitic sills flanking the granite about 30 yards distant from its margin. Their foliation planes correspond with the cleavage planes of the slate between which they are intercalated. Microscopic examination (3364) shows them to be granite and to be allied to that rock rather than to the elvan dykes, with which their mode of occurrence would otherwise suggest their correlation. Their N.N.W. direction, moreover, parallel to the granite boundary is nearly at right angles to the trend of the elvan dykes of the district. The evidence suggests their modification by pressure before final consolidation. There is unfortunately no available section of the granite mass adjoining, so that the nature of its margin at this locality cannot be investigated. The foliation of the granite sills agrees with the foliation of the granite at Kennal Vale, and both correspond in direction to similar planes in the adjoining slates. It has been pointed out that the deformation of the slates is the result of lateral movements acting from S.S.E. to N.N.W. It will be immediately seen that this direction agrees with one of the orientation planes which is common to the whole of the granite—further it corresponds with the foliation of the granite at Kennal Vale and of the granitic sills at Treluswell. We have strong reasons therefore for the assumption that the granite irruptions and the earth movements are not only closely related but that the movements had not ceased to operate before the final solidification of the granite.

Mr. Reid. In the Land's End and Godolphin granite masses no evidence has been found of the foliation or schistosity such as is described by Mr. Hill as occurring in the Carn Menelez granite. There is fluxion structure towards the margin; but the fluxion is parallel to the curved cooling surface, not parallel to the cleavage or other structural planes in the killas. The only sign of contemporaneous or subsequent movement that could be found, besides small faults, is a jointing approximately parallel with the strike of the contortions in the killas. Fractures along planes of weakness in sedimentary rocks, must, however, tend to extend across intruded crystalline masses, and the subsequent intrusion of the elvans along these particular planes seems to show that they did so in West Cornwall.

Digitized by Google

ELVANS.

The mapping of the elvan dykes in West Cornwall is giving a great deal of trouble, for they are so abundant in most of the mining districts that it is important to ascertain what relation they bear to the metalliferous lodes. These dykes with few exceptions rise along the line of strike of the folds in the killas, which also happens nearly to correspond with the strike of the cleavage. They seem to be intruded along planes of weakness, and are probably connected with granitic masses below; they do not radiate from the granite bosses seen at the surface. In lithological character they vary considerably, though a common type of elvan somewhat resembles the fine-grained granite of Gulval Downs. It cannot yet be proved, however, that any of these dykes are contemporaneous with this granite. Some of them penetrate the older granite, but none can be found near the newer mass, which, however, appears in an area in which no elvans occur. North-west of a line drawn from Whitesand Bay through Hayle north-eastward, elvans seem to be absent. Mr. Reid and Mr. Dixon.

Though several of the elvans are schorlaceous and metalliferous, this impregnation seems to be a metamorphic change belonging to a late stage. Two series of intersecting elvans, near Rosewarne and Gwinear, have been examined by Mr. Dixon. He finds that an older series of non-metalliferous quartz-felsites, having a fairly constant north-east and south-west strike and northerly hade, is cut by a newer series of almost non-porphyritic felsitic dykes of somewhat different character, having a more westerly strike, and in some cases, at least, having a hade to the south. These newer dykes are schorlaceous and metalliferous, or are closely associated with metalliferous lodes in the killas; the older dykes, on the other hand, appear only to contain ore where they come within the influence of the newer group.

The elvan dykes are very unevenly distributed over the area north of Falmouth, examined by Mr. Hill. They attain their greatest development in a belt of country extending from the granite margin at Gwennap through Perranarworthal to Kea, diminishing in extent towards Truro—beyond which place in the ground mapped as far to the north-east as Probus they have not been noticed. Similarly in the region lying to the south-east of Gwennap, except for a small group in the neighbourhood of Penryn, their occurrence is insignificant. It may be noted that the belt of elvans between Gwennap and Kea marks the beginning of the great metalliferous region extending from Gwennap to Camborne. In this elvan belt, the quantity of vein quartz is so enormous that the soil is materially impoverished, and over a great portion the slates contain knots, although far removed from the nearest visible granite—the knotting, however, is of a more minute type than that displayed in the aureole of metamorphism which flanks the granite. The Gwennap group of elvans has not yet been traced as far as the granite margin, but in the district lying to the south-east one elvan only has been traced within the granite. It has been followed for over a mile from Towntanna Mr. Hill.

Digitized by Google

Mr. Hill. to Trevales. In size, the elvans range from a few feet to many yards in thickness. A dyke, however, of abnormal dimensions has been traced following an east and west course through Gwennap, and attaining a width of 150 to 200 yards. This dyke has been followed for two miles, and its westerly extension towards the granite margin has not yet been reached. The general direction of the elvans is north-easterly to east-north-easterly. Their hade is usually very steep, and so far as observations have gone they appear to incline more frequently to the north-west than to the south-east. They exhibit, however, much variation in this respect, and sometimes lie nearly flat. They vary considerably in texture, from extremely fine types to examples so coarse that their porphyritic felspars may attain a size of ¾ inch. The felspars consist of both orthoclase and plagioclase. Quartz occurs in blebs, and often with a bipyramidal habit, crystals sometimes exceeding ¼ inch in size. White mica is more abundant than biotite, occurring not only as an original constituent but as a decomposition product of the felspars. A characteristic feature of the elvans is the tendency for the white mica to assume a radiating or plumose habit, and in the matrix of the rock to combine with the felspar in forming a pegmatitic structure. This granophyric habit in connection with the white mica is general amongst the elvans. It is not confined to the micro-pegmatitic type, but pseudo-spherulitic structures are also noticed. Felspar and quartz occur as crystals of an earlier generation than the matrix. Not only are the crystals penetrated by the ground mass, but there is a tendency for silica to aggregate round the quartz grains. The felspar shows a marked tendency to decompose, much white mica being developed as an alteration product. In some instances the plagioclase may be noticed altered to white micaceous substance, while the potash felspars are little decomposed. The decomposition of the felspars proceeds often from the central core, and selvage edges of shrinkage have been observed bounding the felspar crystals.

CHINA STONE.

Mr. Reid. The china stone is granite altered, and with its felspar kaolinised *in situ*, apparently by the solfataric action of fluoric and boracic vapours. This decomposed granite occurs, as is well known, in enormous irregular masses or pipes which seem to have an indefinite downward extension—at least they show no sign of narrowing at the greatest depth to which they have been worked. The distribution of these masses is peculiar, and strongly supports the view that they represent channels along which the vapours escaped. There is one mass in the middle of the Land's End granite about midway between Penzance and Cape Cornwall; there is another mass in the centre of the area of newer granite now first recognised. A third mass occurs about the middle of the Godolphin granite. In each case a vent seems to have occurred in the highest part of the granite dome, and only one such vent has been discovered in each boss. Whether this rule will hold good for other districts remains to be seen.

Digitized by Google

DEVONIAN.

Mr. Ussher has been engaged on the Devonian rocks of east Cornwall, completing the survey of the new series map sheet 348, and carrying the work westward into the adjoining sheet 347. The strata mapped embrace all the Lower Devonian divisions, Middle Devonian slates and slaty mudstones, and in the neighbourhood of Quethiock slates and schalsteins which may belong to the Upper or Middle Devonian, or wholly to the former group. The Lower Devonian rocks are the westerly continuation of those of the Looe area. Up to 1901 the Lower Devonian succession had never been satisfactorily established, an unbroken sequence of the constituent subdivisions having been nowhere encountered. Mr. Ussher.

A few days devoted to the comparison of coast sections has greatly facilitated field work during the last two months of the year, and coupled with the identification by the palæontologist of the fossils collected in 1900 in the Torquay promontory, has yielded more satisfactory results than have heretofore been obtained. These results have a direct bearing on every Lower Devonian district in South Devon, and will, it is confidently expected, much facilitate future work in Cornwall.

The year's work in the field, and in reviewing the evidence, tends to place the Dartmouth slates at the base of the Lower Devonian. These slates often exhibit pronounced green and purple tints, and delicately blended mottling of purple and pale purple and grey; but these characteristic colours often give place to buff and drab tints, and grey, and even blackish slates may be found. The slates are often siliceous; they present glossy surfaces and contain beds of very hard grit and arenaceous rocks. The hard grits or quartzites, both in the area east of Fowey, and in the Kingswear promontory, locally result from the amalgamation or welding together of siliceous shales or slates. On the whole, the aspect of Dartmouth slate sections suggests a coincidence between bedding and cleavage; but when attempts to procure cleavage-dips are made, the angles of schistosity are found to vary, and occasionally hard grits are seen to cut off the planes of schistosity in the slates. From many indications of local irregularities, there can be little doubt that the slates of this series, where they seem to present a continuous succession, are constantly repeated by sharp folds which have been broken and sheared out. In the coast west of Polperro and south of Lansallos, the association of grits in the slates is the same as that displayed on the Revelstoke coast. Many contortions are exhibited by them, including the vertically zigzagged bedding so frequent in the Devonian rocks of south Devon and east Cornwall. These slates have now been traced from the Kingswear promontory westward to the Fowey estuary. In this extension their persistence is only broken near East Allington, in the Kingsbridge area.* The problem of the geological

*See Map in Rep. of Easter Excursion, 1901. *Proc. Geol. Assoc.*, vol. xvii., p. 121.

Digitized by Google

Mr. Ussher. structure of Cornwall, south and west of a line between Fowey and Watergate Bay, is precisely similar to that of the Kingsbridge and Torcross area, in both cases we have partly fossiliferous rocks on the south of the Dartmouth slates. What are their relations to the Dartmouth slates: are they newer or older? If the former these slates must be regarded as an anticlinal; if the latter, as an outcrop, any impersistence in which can only be explained by fault or change in character.

In the *Summary of Progress* for 1900, pp. 60, 61, reference is made to fossils collected in the Torquay promontory, the Kingsbridge area, and the Looe area; the results of the examination, re-examination and comparison of these fossils were received from the Palæontological Department in January, 1901, together with a list of fossils collected by Mr. Upfield Green, from Looe and Fowey.

From these lists the following fossils may be taken as characterizing the Looe and Fowey fauna:—

Orthotetes hipparionyx	Rhynchonella pengelliana (scarce)
Spirifer primævus	Pleurodictyum problematicum
Streptorhynchus gigas	

In the badly preserved fossils of the Kingsbridge area (Ringmore beds) all the above except *Rhynchonella pengelliana*, have been recognized as far as the condition of the crushed casts and impressions would permit. In the Torquay promontory (New Drive) *Orthotetes hipparionyx* occurs in a fossiliferous horizon containing numerous fragments of spined *Homalonotus* and casts of *Strophomena latecosta* (also in the New Cut and on Oxlea Hill). *Spirifer primævus* was found in the Meadfoot beds near Hopes Nose with a *Homalonotus* resembling *H. Rœmeri*, *Strophomena rhomboidalis*, Zaphrentidæ, &c. *Rhynchonella pengelliana* was doubtfully identified by Mr. Etheridge among fossils collected by Champernowne from the New Cut. Davidson thought that he recognised it amongst fossils collected by Mr. Whidborne in the Saltern Cove railway cutting. *Streptorhynchus gigas* is given in Tawney's lists amongst fossils collected west of Hopes Nose Raised Beach, presumably from the uppermost grits of the Lower Devonian. *Pleurodictyum problematicum* is common in the Torquay promontory, and confined to no special horizon. As the Lower Devonian rocks of Torquay and Paignton are all above the Dartmouth slates, which do not appear at the surface, and palæontological evidence is all in favour of the correlation of the fossiliferous strata with those of the Looe and Fowey area, which unquestionably are represented in the Kingsbridge area, it follows that the Dartmouth slates are the lowest member of the Devonian of South Devon and of Cornwall as far west as the Fowey estuary.

The Torquay promontory is, perhaps, the worst tract in the south-west of England to obtain evidence of the actual sequence of the Lower Devonian rocks, owing to faults and contortion. The coast section south of Brixham has not yet been actually

Digitized by Google

compared with the Plymouth and East Cornwall sections, and the comparison of the Ringmore section is not yet completed. In both these sections the Dartmouth slates appear to be in contact with dark slates, which in the Ringmore section pass up into the fossiliferous beds. Mr. Ussher.

In the Plymouth section the practically unfossiliferous Staddon grits are well developed; they rest on grey slates with hard grit beds and bands, presenting at Boveysand the same relation of pronounced cleavage broken by bedding planes that is so pronounced in the grey slaty siliceous rocks forming the coast line between Fowey and Pencarrow Head. The grey slates succeeding these beds in the Plymouth section contain *Zaphrentidæ*, and in parts of the section the bending or distortion of the cleavage planes at intervals is the only indication of bedding. At the south end of Crownhill Bay the slates become calcareous and pass into red very fossiliferous decomposed friable slaty beds crossed by limestone bands containing monticuliporoid corals, &c., identical in all respects with the red and grey limestones associated with the Looe beds at East Looe beach and at Millendreath. These beds are associated with hard fine-grained grits of the same type as those at Beesands, south of Torcross, and they are faulted against the Dartmouth slates at Andurn Point. This faulted north boundary of the Dartmouth slates extends eastward to Modbury.

Turning to Tregantle on the Cornwall coast, we find a great development of the fossiliferous beds identical in every respect with those of the Plymouth section, which when traced inland are seen to contain the same grit types as at Looe and in the New Cut near Torquay. Between these beds and the purple and green mottled Dartmouth slates, on the east and on the west, grey and dark grey slates, with grit beds and arenaceous interbanding in part, form the cliffs. Traces of *Pteraspis* have been found in these slates toward Portwrinkle, so that in part they belong to the Dartmouth slate series, and form a passage into the overlying beds of the Meadfoot series. In the *Summary of Progress* for 1899, page 84, these slates are referred to, and their connection with the Bindown and Congorlan quartzites is correctly foreshadowed. During the latter part of the year 1901, general boundaries were drawn in the area between Lanreath and Polperro separating the grey slates and grits from the variegated Dartmouth slates on the one hand, and from the more or less fossiliferous slates and grits which represent the Looe beds on the other. The latter is a purely tentative line and could not be continued eastward, but there are indications of the development of the local characters of this intermediate series westward. Just north of Lanreath the Dartmouth slates appear in an impersistent mass or masses cut off by a fault on the north, and bounded by dark slates on the south. Here, therefore, as at Bindown and Congorlan the Dartmouth slates appear on the north of the fossiliferous Looe rocks, in which, although there are evidences of crinoids and occasional fossil traces (in slates of Ringmore types), few markedly

Digitized by Google

Mr. Ussher. fossiliferous beds were encountered, probably owing to the absence of good exposures. The grey slates with hard grit beds and arenaceous banding are, however, well evidenced, both on the north and south of the Dartmouth slates, which they separate from the fossiliferous grits and slates of Pencarrow Head, rightly correlated by De la Beche with the fossiliferous rocks of Looe. The Dartmouth slates would therefore appear to form an anticlinal 1½ miles in breadth, bounded by practically unfossiliferous slates, grits, sandstones, and interbanded argillaceous and arenaceous rocks, which for convenience of reference may be provisionally termed Lower Meadfoot beds. An interesting section of these beds is afforded by the south shore of Point Pill Creek, where they are faulted against purple and green Dartmouth slates on the north. In this section grey and dull greenish-grey slates, variegated with buff and straw-coloured tints, and in places associated with beds of tough buff silty rock, and occasionally of hard grit, strongly resemble the variegated slates and arenaceous rock of Mr. Hill's Falmouth series. A faulted development of buff or silty rocks of a type common in the Pelynt district occurs in them. Grit beds here and there show sharp folding, and in one place a mass of tough dense grey grit suggests the local development of beds similar to those of Bindown and Congorlan. Near Brawn Point blue and straw-coloured slates exhibit cleavage planes dipping at a low angle with small wavy undulations due to the intersection of slightly harder silty intercalations. Near this, fossiliferous beds come on which include thick bedded yellow-brown arenaceous rocks, in part very similar (honeycombed with distorted fossil cavities) to the fossiliferous beds of the Tregantle and Plymouth coast sections, and on the same line of strike with the fossiliferous beds of Pencarrow Head.

It is important to note that an argillo-arenaceous or silty character, similar to that displayed in the Point Mill Creek section, is frequent in the Looe area, and in the absence of fossils this deterioration of grits, belonging to the fossiliferous series, cannot be distinguished from similar associations in the Lower Meadfoot beds. The Staddon grits exhibit a similar deterioration traced westward, being locally an argillo-arenaceous series in which more or less silty mudstones predominate over the harder grit beds. The assimilation of different horizons in the Lower Devonian, through the assumption of practically identical lithological characters, renders the mapping extremely difficult and most unsatisfactory where faults have to be drawn, as is the case with a west-south-west fault cutting out the Dartmouth slates of Bindown and Congorlan, which is shifted by an exceedingly indefinite cross fault, and in further prolongation forms the north boundary of the patch of Dartmouth slates north of Lanreath.

CARBONIFEROUS.

Mr. Teall's microscopic examination of the Wearde grauwacke and similar beds at Forder Lake, both near Saltash, proves that

Digitized by Google

these rocks are made up of quartz, felspar, fragments of felsitic and (locally) andesitic igneous rocks. His examination of Culm grits from near the River Tavy south of Abbey Bridge, Tavistock, entirely favours the correlation of the Wearde Efford rocks with the Culm grits (base of Middle Culm Measures), as suggested by Mr. Ussher.* The conditions under which they were formed are explained in the paper here quoted. Mr. Ussher.

During 1901 exceptional opportunities for observing these beds were afforded by the cutting of a new road south of Lower Compton village, and in a deep section driven northward into the hill on which they are best developed. The grits, in even beds separated by masses of dark shaly slate, vary in grain and hardness, and in places present the character of a fine breccia or tuff containing numerous small pieces of shale. The excavation terminates in a mass of exceedingly hard igneous rock. In Lower Compton road the section begins with vesicular volcanic rock, succeeded by very hard even-bedded grits, with shaly intercalations and coarse and fine fragmental rock containing pieces of shale, &c.

PLIOCENE.

The survey of the Land's End district has led to the discovery of one outlier of Pliocene deposits besides that already known at St. Erth. The new outlier occurs on the ridge north of Cannon's Town, on the opposite side of the valley to the St. Erth pits, and at an elevation slightly greater (150 feet). It consists merely of the ferruginous pebbly sand or soft sandstone known as "growder," the fossiliferous clays seen in the St. Erth pit being missing. The search for Pliocene deposits has, however, resulted in the discovery of a striking feature in Cornish geology. In describing the St. Erth deposit reasons were given for thinking that the fossiliferous clay indicated a depth of water of 40 or 50 fathoms, and nothing that has since been discovered has led us to modify this view. † If this view is correct we ought to find traces of a Pliocene shore-line near the 400 foot contour, for the fossiliferous clay lies about 120 feet above the present sea-level. When the deposit was examined in 1886 no shore-line could be found in the neighbourhood, for all the country near St. Erth lies below the 400 foot contour, and shows signs of having been planed and smoothed by the sea. Out of this undulating plateau, however, rise in the distance various abrupt and more rugged hills, and the examination of the whole district has now shown that a clearly-defined ancient shore-line bounds this plane of marine denudation at a height of about 420 feet above the present sea-level. Mr. Reid.

Notwithstanding the strong presumption that the plateau was once occupied by Pliocene strata, and that the old cliff marks the

* *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlvi., p. 50, 1900. See also *Trans. Inst. Mining Engineers*, vol. xx.

† "The Pliocene Deposits of North-Western Europe." *Nature*, vol. xxxiv., p 341 (1886); The Pliocene Deposits of Britain, "*Memoirs of Geol. Survey*," chapter v. (1890).

Digitized by Google

Mr. Reid. former limit of these strata, it is exceedingly doubtful whether the whole of these features were of Pliocene date. The plateau is so extensive, and is cut in such hard rocks, that it is difficult to imagine that the Pliocene sea could have levelled it. Perhaps after all it is a feature of much older date, merely cleaned up and sharpened in Pliocene times. In support of this view, we can point to the very similar plateau in Gower, described in Mr. Strahan's report (p. 49), for on that plateau have now been discovered two outliers of Trias. It is hoped that further work in Cornwall may throw light on this striking feature.

RAISED BEACHES.

Thus far no Pleistocene deposit older than the raised beach has been recognised in West Cornwall, though there are indications that the whole coast is fringed with a more ancient erratic deposit, which lies entirely beneath the present sea-level. The numerous small erratic blocks which occur in the raised beach probably belong to this older deposit; for nothing has yet been found in the newer one to suggest anything but a temperate climate, and the foreign stones in the raised beach are all sufficiently small to have been brought up during storms from a depth of 5 or 10 fathoms attached to the roots of oar-weeds. The larger blocks, so often found in dredging and trawling, do not seem to occur in the raised beaches.

The highest raised beach yet discovered in Cornwall is seen in Penlee quarry, near Newlyn, where coarse beach-shingle rests on a rocky shelf 65 feet above Ordnance datum. The old cliff and beach can be traced at about this level through Penzance, and sweeping round Mounts Bay behind the marshes. It is recognizable also at frequent intervals round the coast, as a notch and narrow steeply-sloping ledge, more or less hidden by head and talus. Everywhere it yields erratic stones, though these are especially abundant where, facing the raised beach, is found a considerable extent of shallow sea. The foreign rocks are mostly subangular Chalk-flint and Greensand-chert, like the altered rocks found in the Bagshot gravels of Devon, and pebbles of a hard purple sandstone of doubtful origin. These occur everywhere, but at Cape Cornwall was found also a single pebble of biotite-trachyte or biotite-andesite closely resembling some of the Permian volcanic rocks of Devon, though unlike anything belonging to Cornwall.

WATER SUPPLY.

Another season of deficient rainfall caused great anxiety as to the water-supply of many Cornish towns and watering-places. This question is a very difficult one to deal with, for great part of the country has been so riddled with mines that the water

Digitized by Google

drains away far more rapidly than was formerly the case. Besides this, great caution has to be used as to the source of the supply, for though the limited inland population in most of the area examined in 1901 renders it fairly easy to avoid surface contamination, yet the common occurrence of copper-salts in solution necessitates the rejection of many copious sources. Mr. Reid.

Penzance is now undertaking new works for increasing the water-supply by tapping the elvan which crosses the altered killas near Madron. These elvans are often valuable sources of water-supply in Cornwall, though in different cases they behave very differently. The porous much jointed elvan near Penzance forms a dyke in the more impervious killas, and seems to act as a channel, probably conducting a good deal of water from the granite hills above. In other cases, decomposed or kaolinised elvans form clayey dykes which dam up the water, so that its level is much higher on one side than the other.

SOILS.

The soils over parts of the Land's End district have already been alluded to, but it may be remarked that for market gardening, flower culture, and dairy farming, which are now becoming so important in Cornwall, the nature of the underlying rock and the chemical composition of the natural soil are only two of the requirements. Cornwall depends so largely on the production of vegetables and flowers earlier than, or at seasons different from, other parts of England, that aspect and shelter are even more important than soil, especially as the soil is so freely enriched and altered by heavy dressings of shell-sand and sea-weed. Some of the best land for this spade culture is found where the slopes face the sun, as they do around Penzance, and at the same time have a mixed soil of greenstone and killas, lightened by a coarse, sandy wash from the granite above.

Not only is the soil greatly modified by intentional transportation of sea-sand, but it must also be changed by wind-borne dust for much greater distances than is usually thought. Last year, during gusty E.N.E. winds, at Carbis Bay, from a height of 270 feet above the sea, swirls and puffs of dust were seen to rise from the desert-like flat at the mouth of the Red River to a height of at least 240 feet. They nearly blotted out Godrevy Towans (230 feet) and Godrevy Lighthouse, and then spread in a well-defined belt across St. Ives Bay for over three miles to near St. Ives Head, which the belt must have passed.* Soils thus modified by dust and calcareous sand cover most of the rock near Hayle and Lelant.

The *granite* in the Falmouth area forms a dome-shaped table-land and supports a soil adapted for cultivation. Knolls of solid rock appear at random above the soil and on the slopes of the valleys, but apart from these rocky exposures the ground forms good arable land. The disintegration of the granite, however,

* See Reid, *Nature*, March 6, p. 414.

Digitized by Google

Mr. Reid. yields a somewhat cold soil, and crops are not so advanced as on the slate-bearing ground.

Mr. Hill. *The Portscatho series* yields a generous soil, which is considerably enhanced by the arenaceous beds, which, keeping the soil from becoming too coherent, admits of the ready passage of the surface drainage. The rocks of this division, however, are everywhere carved into deep valleys, the slopes of which are often so steep that the surface soil is washed off to the lower grounds, resulting in a hill slope comparatively barren.

The Falmouth series produces some of the richest land, and this is especially the case where the soft, sandy beds predominate. The presence of so much more iron in its chemical composition will account for its comparative superiority in this respect to the other sedimentary divisions. This division has a tendency to form lower ground, and shows no disposition to the formation of steep valleys, so that barren land within this division is exceptional.

The *Mylor Slates* in this district support a soil inferior to the other sedimentary divisions. This is largely due to the fact that it flanks the granite, the marginal portion of that mass and the adjoining slates being the metal-producing zone, so that it has been extensively veined by quartz. The quartz *débris* scattered over the ground is sometimes so great that the surface soil consists of little else, and the land is out of cultivation, while in other districts the agricultural land is considerably impoverished from this cause. Where these conditions, however, do not prevail, the soil is little inferior to that of the Portscatho or Falmouth divisions. This division has a tendency to form uplands with shallower valleys than are found in the Portscatho series.

3. South Wales District.—Glamorganshire and Carmarthenshire.

Mr. Aubrey Strahan, District Geologist.

Mr. R. H. Tiddeman
Mr. B. S. N. Wilkinson
Mr. T. C. Cantrill
Mr. H. H. Thomas
} Geologists.

Ordovician Rocks.

Mr. Strahan. The surveying of Sheet 230, which includes the North Crop of the coalfield from Ystradgynlais to Mynydd Mawr, has necessitated the mapping of some of the older rocks near Llandilo. The Ordovician Rocks enter the sheet with a strike of W. 30° S., which, however, curves westwards to nearly east and west. The movement to which this strike is due has been so energetic as not only to place the strata of a broad belt of ground in a vertical position, but to give rise to over-folding and over-thrusting. All the rocks up to the Coal Measures are involved, but the effects of the movement are manifested chiefly in the older rocks, and to a

Digitized by Google

less degree in the Carboniferous areas, though it has sufficed to tilt the limestone and Millstone Grit at an angle of 45°, and to plicate the Coal Measures near Llandybie. Mr. Strahan.

Proof has been obtained of the existence of movements of more than one age, but the dominant, and perhaps the most recent, has been that to which the present strike is due. By its direction this disturbance links itself on to those of Cribarth and the Vale of Neath. These well-marked belts of compression range about W. 30° S., and succeed one another at fairly regular intervals. Thus the Vale of Neath disturbance is followed, after an interval of seven miles, by the Cribarth disturbance. Cribarth is followed, at seven miles distance, by the Tair Carn anticline, and that anticline, both by direction and situation, is connected with the upheaved belt of Ordovician and Silurian rocks.

Of the age of this system of movements we have no direct proof, but the work has shown that it was probably not contemporaneous with the pre-Triassic east and west folds of the South Crop. Neither the Vale of Neath nor the Cribarth disturbances link themselves on to that system, either in character or direction.

It has been observed, by both Mr. Cantrill and Mr. Thomas, that the dip of the Silurian rocks is generally steeper than that of the Ordovician. Both dip to the south, but the Silurian at 70° to 80°, while the older rock dips at 45° to 60° only. If the junction were an unconformity and not faulted, this could only be accounted for on the supposition that the Ordovician strata had had a northerly dip before the Silurian rocks were deposited; but the evidence for a great fracture is so convincing that we may adopt the explanation that the difference in inclination is due to two portions of a great **S**-shaped (sigmoidal) curve having been faulted into juxtaposition. Thus the Ordovician rocks have the angle of dip proper to the upper limb of the **S**; while the Silurian rocks have the steeper dip which prevails in the central limb.

The district is traversed also by some clean-cut normal faults of the N.N.W. direction. A good example of such a fault has been traced by Mr. Thomas from Bryn Martin Uchaf to the Keeper's Lodge at Llanfihangel, the shift of outcrop being as much as 100 to 150 yards in highly-inclined beds; but no case has been found of a N.N.W. fault traversing the whole of the belt of disturbance referred to above. The results of the detailed mapping are recorded by Mr. Cantrill as follows:—

The Ordovician rocks are excellently exposed in the sides of the River Cennen and in a railway cutting at Ffairfach. They show the following sub-divisions in descending order:— Mr. Cantrill.

3. Flags and Limestones	}	Llandilo Beds.
2. Ffairfach Grit	}	
1. *Didymograptus*-Shales.		Llanvirn Beds (?)

Digitized by Google

Mr. Cantrill and Mr. Thomas.

1. The *Didymograptus*-Shales* are somewhat micaceous black shales and mudstones, containing numerous *Didymograptidæ* with a few *Lingulæ* and trilobites. Their base is nowhere seen, but the shales are probably at least 300 to 400 feet thick. They pass up into a more sandy and micaceous rock with few or no fossils. In carrying on the work westwards Mr. Thomas estimates that the unfossiliferous micaceous part of the shales is 150 feet thick, and that the graptolitic shales are exposed to a thickness of probably more than 200 feet. He finds *Didymograptus bifidus* to be the commonest form, but the classification of the beds will depend upon further identifications.

2. The Ffairfach Grit is described by Mr. Cantrill as a hard, yellowish sandstone, grey and calcareous when unweathered, and about 150 feet thick. It is found by Mr. Thomas to pass in places into a sandy limestone, apparently unfossiliferous. It is well exposed in the Ffairfach cutting and under the terrace of Golden Grove House.

3. The Flags and Limestones of the Llandilo group, as shown in the Ffairfach cutting, consist of about 150 feet of thin-bedded, dark grey sandy mudstones, overlain by 150 feet of pebbly, soft sandstones, above which, again, come dark flags and limestones, often weathered into rottenstones. The outcrop in the Cennen Valley is found by Mr. Cantrill to be two-thirds of a mile broad, which, with a dip ranging from 40° to 70°, indicates an *apparent* thickness of about 2,500 feet. The top of the flags is not seen. In reference to these rocks farther west, Mr. Thomas writes that the limestones cannot be traced far, owing to their habit of weathering into rottenstone, but that they are not so sporadic as would appear at first sight. A large mass occurs in an old quarry in Golden Grove Park. He finds in the flags and limestones an abundance of fossils, chiefly trilobites and brachiopods. Here, also, proof is obtained of a great gap between the highest seen Ordovician and the Silurian rocks, the upper Llandilo being absent in Mr. Thomas's opinion, as well as the Bala and Llandovery series.

SILURIAN ROCKS.

Llandilo.

Mr. Cantrill.

The development of hard red and grey pebbly grits (Passage Beds) forms one of the most conspicuous features in the highest Silurian rocks near and east of Llandilo. These strata form a well-marked ridge extending from Trichrug, where they are well developed, westwards towards Storm Hill, but farther west they disappear, partly through an unconformable overlap by the Old Red Sandstone, but not less by gradual attenuation in themselves. In the eastern part of their range, at Cilmaenllwyd, Mr. Cantrill finds the following descending succession :—

* This name was introduced by Messrs. Marr and Roberts. *Quart. Journ. Geol. Soc.*, vol. xli., p. 476 (1885).

Digitized by Google

Old Red Sandstone: red micaceous marls, containing *Lingulæ* for about five or six feet above their base, passing down into Mr. Cantrill.

		Ft.
Passage Beds.	Tilestones: yellow, highly micaceous sandstones formerly wrought for tiles; fossiliferous; about	150
	Trichrug Beds: red sandstones and grits and sandy marls, mostly pebbly; passing down into yellow grits at their base	600
	Grammysia-beds: dark purplish-grey, flaggy sandstones, with thin seams crowded with fossils, among which *Grammysia* is very abundant; about	180
Ludlow and Wenlock.	Greenish-buff mudstones, with thin harder seams, and below them several bands of hard yellow sandstone, one about 150 feet thick, for which the name of Lletty Grit will be convenient	2000
	Greenish-grey mudstones	

The last-named may be assigned to the Wenlock group. In carrying on the account westwards, Mr. Thomas observes that both the Tilestones and Trichrug Beds have disappeared near Golden Grove Park, leaving the Old Red Sandstone in direct superposition upon Ludlow mudstones. In the same neighbourhood the base of the newer formation becomes conglomeratic and contains angular fragments of the underlying mudstone. Between the Ludlow and Wenlock he finds that no hard-and-fast line can be drawn. The Lletty Grit, one of the most constant of several grits which make their appearance in the middle and upper parts of the Silurian mudstones, is about 180 feet thick, and can be traced on. Sandstones are, on the whole, thicker and more abundant in the upper than in the lower part of the mudstones. Fossils abound along certain lines, not, however, in the grits. Amongst others he has obtained *Calymene Blumenbachii, Phacops caudatus* and other trilobites, with *Atrypa reticulata, Leptæna rhomboidea, Cyrtia exporrecta*, etc. Mr. Thomas

With respect to the junction of the Silurian and Ordovician rocks near Golden Grove, Mr. Thomas makes the following note:—

The lowest Silurian rocks are greenish-brown or buff mudstones, with thin bands of sandstone. These are of Wenlock age. They rest sometimes against Llandilo flags, sometimes against the Ffairfach Grit, and sometimes against the *Didymograptus* shales. The junction is therefore either an unconformity of great magnitude, or a fault. But though it is exposed in four places, the base of the Silurian rocks contains no trace of conglomerate such as might have been expected in the case of a great unconformity. On the other hand, there are indications that the Silurian mudstones have been indurated near the junction, and that in both them and the Ordovician a cleavage has been developed, with traces of foliation along bedding-planes. At the back of Golden Grove the junction is laid bare by a stream for 250 yards, and here it is actually seen to be a fault, accompanied by much crushing on both sides, and signs of shearing in the neighbouring beds. The

Digitized by Google

Mr. Thomas. evidence points to its being a fault in all other parts also of the district mapped. The conclusion is in accord with Mr. Cantrill's observations. At an exposure of the junction at Troedyrhiw he finds that the Silurian rocks dip at an angle of 40° *towards* vertical Llandilo beds, and concludes, both from this and the absence of conglomerate, that the junction is a large fault, or perhaps a thrust.

Gower.

Mr. Strahan. Two inliers of Silurian rocks have been found this year in Gower. They had escaped notice in the original survey of South Wales, and were not known to exist until they were detected by Mr. Tiddeman. The larger of the two forms an undulating table-land on the north side of the ridge known as Cefn-y-Bryn. The Old Red Sandstone composing the ridge dips southwards, and from beneath it emerge soft, olive-coloured shales, the junction between the two being sharply defined. The inlier, though two and a half miles long, is narrow, being bounded on the north by a fault which throws down various members of the Old Red Sandstone and the Lower Limestone Shales in succession.

Mr. Tiddeman. The smaller inlier lies north-west of Penmaen Workhouse. On its east side it is bounded by a fault which crosses the anticline of Cefn-y-Bryn obliquely; but towards the south-west it is succeeded naturally by Old Red Sandstone. The shales are poorly exposed, but Mr. Tiddeman obtained fossils, which were identified by Mr. Newton as:—*Rhynchonella* (like *R. nucula*), *Bellerophon* (like *B. Murchisoni*), *Modiolopsis ?*, *Chonetes* sp., crinoid ossicles, entomostraca.

OLD RED SANDSTONE.

North Crop.

Mr. Cantrill. The mapping of the Old Red Sandstone on the north side of the Coalfield has been continued by Messrs. Cantrill and Thomas. With respect to the neighbourhood of Derwydd Road and Trapp, Mr. Cantrill writes that the lowest subdivision, or red marls, is exposed in the Cennen, but that none of the conglomeratic cornstones, so frequent near Gwynfe and eastwards, are present. At Cilmaenllwyd the lowest few feet are highly micaceous and contain a few small *Lingulæ*, survivors, possibly, of the Silurian fauna. Traced westwards, the basement-beds become more sandy and assume a pale-green and yellow colour. No hard-and-fast line could be drawn between these and the Tilestones of the Silurian Passage Beds, the one seeming to pass into the other. This is especially noticeable in an excellent section on the main road to Llanelly, on the west side of the Cennen Valley.

Mr. Thomas. Still farther west, however, the succession is changed. As noticed above, Mr. Thomas finds a marked overlap of the Silurian rocks by the Old Red Sandstone, accompanied by the development

Digitized by Google

of conglomerate in the base of the newer formation. A green tinge prevails at the base of the Old Red Sandstone, and one of the lowest beds is a fissile green sandstone, which has been worked as a tilestone, but which must not be confounded with the Tilestones of the Silurian Passage Beds. Mr. Thomas.

The series of green and dull-red sandstones, to which Mr. Cantrill gives the name of Senni Beds, forms the lower part of the Brownstones, and has been traced continuously so far as the surveying has proceeded. The great mass of the Brownstones above repeatedly yields exposures, but whereas in the Carmarthen Fans the beds consist of innumerable alternations of sandstone with marl, farther west marls form the bulk of the subdivision. The quartz-conglomerates, also, which form the scarps of the Carmarthen Fans persist no farther west than the Clydach Valley. It thus happens that the Grey Grits, or uppermost subdivision of the Old Red Sandstone, there rest upon marls Mr. Cantrill.

A little farther west, however, the Grey Grits disappear, but to the south of Trapp an olive-green sandstone with quartz-pebbles comes in at a probably lower horizon below the Lower Limestone Shales. At Llandyfan, where the rock is about 20 feet thick, and contains rolled flakes of dark shale, it is separated from the Limestone Shales by 150 feet of coarse red sandstone and red marls. North of Llandybie the upper beds of the Brownstones tend to become still more sandy, as is well shown at Cilyrychen Quarry, where the Lower Limestone Shales, with a few feet of dark green sandstone at their base, rest upon green, red and brown sandstones and marls with conglomeratic cornstones containing fossiliferous pebbles.

The disappearance of the Grey Grits has been traced by Mr. Cantrill step by step from the Carmarthen Fans, by the head of the Cennen, where they are pebbly and 15 feet thick, to Banc Wern Wgan, where they are devoid of pebbles and only 8 feet thick. Farther west they are represented by only about 6 feet of greenish-brown grit, separated from the Lower Limestone Shales by a few feet of red marls; but no obvious representative of the Grey Grits has been recognised west of Cwrt Bryn-y-Beirdd.

Gower.

In Gower the Old Red Sandstone has been found by Messrs. Tiddeman and Wilkinson to occur in the form of sharp anticlinal folds, running approximately east and west. In nearly every case, however, one limb of the anticline is replaced by a fault. The following subdivisions are recognised:— Messrs. Strahan, Tiddeman, and Wilkinson.

White quartz-grit (the Grey Grits), freely charged with pebbles of vein-quartz.
Red ditto ditto
Red and purple sandstones (the Brownstones).
Red and purple marls, with an occasional conglomeratic cornstone.

Digitized by Google

Messrs. Strahan, Tiddeman, and Wilkinson.

The last named are not often visible, and may be absent on Cefn-y-Bryn. The red sandstones, which are usually conspicuous, graduate up into the red conglomerate, but there is a fairly well-marked boundary between the red and white conglomerates. In one case noted by Mr. Tiddeman pebbles and fragments of hæmatite occur in the Old Red conglomerate.

The detection of Ludlow Beds in the Cefn-y-Bryn anticline has changed our views with respect to the development of the Old Red Sandstone. From a rough estimate the thickness of the latter formation in Cefn-y-Bryn can scarcely exceed 400 feet, though it amounts to 3,500 feet near Cardiff and to still more in the Brecknock outcrop. Moreover, in Rhossili Hill there are beds represented which are absent in Cefn-y-Bryn, and a greater thickness of the Brownstones and marls exposed, without reaching the base. The attenuation of the Old Red Sandstone in Cefn-y-Bryn takes place chiefly in the lowest subdivision, the marls with cornstones, which, indeed, are doubtfully represented by a few feet only; but the Brownstones also, though certainly present, are greatly diminished. The uppermost conglomeratic subdivisions, on the other hand, are well developed. It is clear therefore that the diminished thickness of the Old Red Sandstone is not due either to an overlap by the Carboniferous shales, or to an overlap of the Brownstones by the conglomerates, or apparently to an overlap of the marls by the Brownstones, but to attenuation in the two last-named. These facts suggest an unconformity between the red rocks and the Ludlow shales—a matter which will receive further investigation.

CARBONIFEROUS LIMESTONE.

North Crop.

Mr. Cantrill.

In the North Crop Mr. Cantrill makes the following observations on the Carboniferous Limestone. It presents, in descending succession:—

Rottenstone Series.—Fine-grained, white and yellow sandstone with rotten chert-bands in the upper and rottenstones in the lower part.

Main Limestone 600 to 700 ft.
- Dark limestones with black chert-nodules.
- Light-grey oolite about 50 feet thick; at its base about 15 feet of soft sandstone.
- Dark limestone and oolite. *Lithostrotion irregulare* at base.

Lower Limestone Shales.—About 40 or 50 feet, but tending to thin westwards.

The Rottenstone Series has been exceptionally well exposed in the Bynea Brick Company's "plastic clay" level at Garnbica. There the beds between the Millstone Grit and the top of the main limestone are about 60 feet thick. They consist of yellow sandy material in beds about six inches in thickness, some of which have the flinty and angular fracture, and occasionally the nodular form, of chert, while a very few contain a small core of

Digitized by Google

undecomposed chert. A band of black clay 1½ feet thick, near the middle of the series, may be a decalcified limestone, and at the bottom there is a rottenstone, 12 feet thick, which, however, is too clayey for commercial purposes. The "plastic clay," for which the level is worked, appears to be an impalpably fine "silica-sand." It occurs in thin bands among the harder and coarser material. Mr. Cantrill.

Gower.

Notice has been previously made of some pitted and nodular limestones, which had been observed by Mr. Tiddeman in the upper part of the Carboniferous Limestone at Newton Nottage and in Gower.* He now makes the further observation on these rocks that they are almost always associated with thin coaly beds containing carbonised vegetable matter, such bands having been noted by him at Newton Nottage, Oystermouth, Mumbles, Pwll-du Head, Oxwich Head, Bishopston, Ilston, Llethrid and Llanrhidian. From a smut-bed of this character at Oxwich Head he has obtained a number of small gasteropoda, which may prove to be new to Carboniferous rocks. The section is given by him as follows, in descending order:— Mr. Tiddeman.

Oxwich Point.	ft.	in.
Dark crystalline encrinital limestone.		
Black compact limestone, seen to - - - - - -	20	0
Black calcareous mud with bryozoa - - - - - -		6
Crushed limestone with veins of calcite and *Productus* at top - - - - - - - - - - 2 ft. to	3	0
Brown or black muddy bed with gasteropoda and vegetable remains (? fucoids) - - - - - - 1 ft. to	3	0
Irregular limestone with *Lithostrotion* abundant, also *Zaphrentis* and *Euomphalus*, and occasionally *Stigmaria*; base not seen.		

The nodular limestone series is quite 200 feet thick at Oxwich Head, and is exposed to a thickness of more than 200 feet at Llanrhidian. Mr. Tiddeman proposes to apply to it the name of Mumbles Head Beds.

With reference to the Rottenstone or Bishopston Beds,† Mr. Tiddeman writes that these strata, "as represented by the 'Black Lias' at Oystermouth and the decalcified limestone at Bishopston, have been traced over a wider area than was assigned to them by De la Beche. It is true that they are thickest at Bishopston, but we also find traces of them on the southern side of the peninsula. Thus the rottenstone occurs in pockets in the Mumbles Head Beds at Pwll-du Head, as well as overlying the same beds at Port Eynon at the old paint-mine and on the foreshore. At the paint-mine the *Spirifer* which abounds at Bishopston was found. Traces of the rottenstone have been detected on the northern margin of the Carboniferous Limestone at Ilston,

* *Summary of Progress* for 1900, p. 87.

† *Summary of Progress* for 1900, pp. 87, 88.

Digitized by Google

Mr. Tiddeman. Llethrid, near Cae Morgan, and Cil Ifor. At both the last-named localities *Wavellite* occurred, and they are probably the places hinted at by De la Beche where Logan found this mineral."*

MILLSTONE GRIT.

Gower.

The Rottenstone Beds are followed upwards by Millstone Grit, which consists chiefly of black shales, but at a distance from the limestone corresponding to a thickness of 100 to 300 feet, Mr. Tiddeman finds a fairly persistent bed of compact, almost cherty, sandstone, which breaks up into cubes or rhombs; this band is to be seen at intervals from Bishopston to Llanrhidian. A higher horizon of sandstone bedded with blue and black shale runs parallel with it from Pengwern Farm through the south end of Cillibion Plantation and by Parc-y-rhedyn, but not east from Bishopston. A third still higher sandstone runs through the north end of Cil Ifor Top, though not through the highest point of the hill. This rock has been quarried for building, and certain beds in it serve as freestones. The succession generally presents but little resemblance to that of the North Crop.

North Crop.

Mr. Cantrill. The main subdivisions of the Millstone Grit have been mapped by Mr. Cantrill through the area surveyed this year, but in a slightly modified form. The quartz-pebbles in the basement-grit become scarcer westwards and almost disappear near Careg Dwfan. At the same time bands of shale tend to come in near the base, and Mr. Cantrill thinks it possible that the radiolarian cherts† may be found in a black shale some 10 feet above the base of the grit.

Such a bed of shale has been exposed near the Garn-bica Level. It is 16 feet thick and contains lamellibranchs resembling *Posidonomya*, ostracoda, and plant remains; there occur also beds which look like rottenstones and decomposed chert, but between it and the Rottenstone Beds proper there are some few feet of quartz-grit. Similar shale-bands occur elsewhere, so that there would appear to be an alternating passage up from the Limestone into the Millstone Grit.

The middle or shaly subdivision of the Millstone Grit passes down into the underlying grits. The Farewell Rock or uppermost subdivision runs, as a thin band of olive-brown sandstone, south-westwards of Llandyfan and west of Llandybie.

COAL MEASURES.

The past year's work in the Coal Measures has lain in the North Crop between Glanamman and Llandybie, and in the South Crop between Swansea and Llanelly, including the north side of Gower.

**Mem. Geol. Survey*, vol. i., p. 134.

†Described in the *Summary of Progress* for 1900, pp 88, 89.

Digitized by Google

North Crop.

Mr. Cantrill.

In attempting to locate the base of the Coal Measures along the north side of the Amman Valley, between Glanamman and Ammanford, much difficulty has been encountered through the prevalence of Boulder Clay, the existence of obscure east and west rolls connected with the Tair Carn anticline, and the occurrence of several faults belonging to the N.N.W. system.

The lowest or Astell vein, which at Brynamman serves as a base to the Coal Measures, is represented possibly by a small vein which crops out at Bryn Pedol. Its outcrop probably passes through Cynghordy and Glyndreiniog to Tyllwyd, where it is thrown northwards by the Nant-main or Tyllwyd Fault—a large downthrow west. West of this fault, however, the base of the Coal Measures is conjectural; the lowest veins known being the group formerly worked at Tyllwyd and Brynlloi, which comprises probably the Little Brass, Middle and Lower Veins of Brynamman. Some little exploration has been made upon these, also a little south of Garenig Bridge, but west of the Cwm Garenig Fault their position is unknown; they are presumably thrown northwards and probably crop out under the Boulder Clay on the north side of the Amman. The parallel fault of Glyn Moch, which runs 500 yards farther west and is also a downthrow west, must throw them still farther north, for the Big and Brass Veins crop under the Boulder Clay between Ynys-y-fawnen and Aber-nant, where they were worked at the Llwyn yr hâf Shaft and Drift. West of this point all workings between the Amman and the axial line of the Tair Carn anticline cease. Some veins which are probably low in the Coal Measures crop out and were formerly worked by openworks between Glynhir and Drefach; but their correlation remains doubtful. The same veins should rise again to the north near Llandyfan, but the ground is unproved as far west as the Dinas Fault, near Llandybie. Beyond the fault the lowest veins are known as the Piodau veins.

In the Amman Valley the various ironstones and coals—from the Big down to the Brynlloi—which were extensively worked at Glanamman are cut off by the Cwm Garenig Fault, and except at Llwyn yr hâf are unknown between this fault and the Bettws Fault; the old cropworks at Pontamman and the veins at present worked in the Ammanford Colliery not having yet been satisfactorily correlated.

The Red Vein formerly worked at the old Cawdor Colliery in Cwm Garenig is there thrown down on the west by the Cwm Garenig Fault into the Amman Valley; and again further west by the Glyn Moch Fault. It was formerly worked at Glyn Moch Colliery, and the crop can be traced easily thence as far as the Bettws Fault. At the Red Vein workings of the Ammanford Colliery Co. a clod five feet thick comes in in the middle of the coal and persists westwards.

Several thin veins above the Red Vein have been worked along the crops on the high ground south of the Amman Valley.

Digitized by Google

Mr Cantrill. One of these, known as the Butcher's Vein, has been traced from the Cwm Garenig Fault, past Waun-hir and the Butcher's Arms, into Cwm Cathan, where it is probably the Garn Swllt Vein. This may prove to be the representative of the Ynysarwed or No. 2 Rhondda Vein.

South Crop and Gower.

Mr. Strahan. Field work during 1901 was carried on by Mr. Strahan in the Coal Measures between Loughor and Llanelly and in the northern part of Gower. The inclination of the measures of the South Crop is always high, but in Gower, not far from the western end of the Coal basin, it approaches verticality, and is accompanied by a number of extremely sharp folds. The steepest dips and the folding occur along the outcrop of the lowest measures, which are almost wholly composed of shale; northwards the inclination steadily diminishes, and the massive sandstones which accompany the Dunvant Veins are not only free from folding but form a regular outcrop, interrupted only by the north and south faults. Still farther to the north, after passing a depression due to the outcrop of the Penlan Vein and some soft measures associated with it, we reach the dominant feature of the district, an almost continuous range of hills formed by the Pennant Series.

The Pennant Series, however, of this part of the coalfield differs from that of Monmouthshire in the fact that its upper part includes several valuable seams of coal and thick beds of shale. Thus the Hughes group of coals lies about 500 yards below the Four-Feet Vein, which we take as the top of the series, and crops out along a continuous strike-valley which runs from Swansea to near Penclawdd. Northwards this valley is dominated by a subordinate range of sandstone-hills, on which Wig-fawr and Allt-wen are situated, and this again is succeeded by a northward slope in which the Two-Feet, Three-Feet and Six-Feet Veins crop out, together with some subordinate sandstones. Finally at the edge of the low ground we reach the outcrop of the Four-Feet Vein and the top of those productive measures which we believe to correspond to the unproductive upper part of the Pennant of Monmouthshire.

Thus far the dip has been uniformly to the north, but at an always diminishing angle. The beds at length become horizontal under the alluvial flat north of Gowerton, and then gently rise to form a low anticline which runs through Mynydd Carn-goch, Loughor Upper Town, and south of Broadoak Colliery. The form of the ground, however, corresponds to the dip of the strata, so that the Four-Feet Vein keeps near the surface, without actually cropping out. This Broadoak anticline is followed northwards by a shallow syncline which runs north-westwards under Loughor Common, as proved in old workings in the Four-Feet Vein. The tract lying north of the syncline has not yet been proved. The measures strike due north and south for about two miles and include a group of three seams known as the Grovesend Veins besides one or more thin seams above.

Digitized by Google

Mr. Strahan.

There is much doubt whether the Grovesend Veins are equivalent to the seams which crop out at Melin Llan* and Gelligynore, and, therefore, represent the Four-Feet Seam, or whether they lie above them. The Drift of the Mountain Colliery was commenced in the outcrop of one of the Grovesend Veins and then passed through an upthrow fault into the Four-Feet Vein, which was extensively worked and found to differ in section from any of the Grovesend group. This would seem to prove that the Grovesend group lies above the Four-Feet, but how far above is not known, the throw of the fault never having been proved. On the other hand the Grovesend Veins are said not to match any of the known seams which lie above the Four-Feet in the neighbourhood. A shaft in progress at Cefn-Arda has not thrown any light on the matter so far, for it was commenced a few yards below the Grovesend crop and has been sunk over 250 yards without proving any recognisable seam. If the Grovesend seams correspond to the Four-Feet Vein and Rider, the Five-Feet should have been found in this shaft at about 120 yards depth, and the Six-Feet at about 250 yards depth. Yet if they lie above the Four-Feet, they can hardly be so high above it as the Cefn-Arda shaft seems to indicate, for it would imply that the fault traversed at the Great Mountain Colliery had a throw of not less than 200 yards, in which case it should be traceable both to the north and south of the doubtful region.

Two seams occur above the Four-Feet near Loughor, namely the Loughor Little Vein, 41 yards above it, and the Penyscallen 20½ yards above the Little Vein; a third which is not known to exist near Loughor has been worked to the west of the Loughor Vein under the name of the Gelli Vein; this lies 188 yards above the Four-Feet, and, therefore, corresponds in position to the Drews Vein of Llansamlet and the Bryncoch Vein of the Neath trough. This is the highest vein known in the South Wales Coalfield; it occupies an area of less than a square mile in extent on the east or downthrow side of the Bryn-serfyll Fault.

The sequence of the veins in the Llanelly district corresponds well with that of the Swansea district, but the names are different. A correct correlation is important in estimating the number of seams, if any, that are likely to exist in the Llanelly district beyond those which have been already proved. The accompanying table gives the correlation and the synonyms so far down in the series as the surveying of the district has proceeded. It should be especially noted that the Four-Feet Vein of Swansea becomes the Big Vein of Box and St. David's Collieries, and that the Four-Feet Vein of those Collieries is the Five-Feet Vein of Swansea.

---

* *Summary of Progress* for 1900, p. 99.

Digitized by Google

Comparative Table of the Seams above the Hughes Vein between Llanelly and Neath.

(Distances between seams are given in yards.)

Llanelly District.			Loughor.	Swansea District.	Neath District.
Old Castle Colliery.	St. David's Colliery.	Cae Colliery.	Broadoak Colliery.	——	——
	Gelli Vein 119½ Coal, 1 ft. 10 in. 11½ } 188 Coal, 1 ft. 3 in. 56			Drew's Vein 135 to 180	Bryn Coch Vein 152
	Box Big Vein 98½	Clement's Vein 39 Glyngwernen, or Box Big Vein 83	Penyscallen Vein 20½ Loughor Little Vein 41 Broadoak Vein 96	Four Feet Vein 118	Wernfraith Vein 105 to 110
	Four Feet Vein 64½	Box Five Feet Vein 69½	Five Feet Vein	Five Feet Vein 76 to 87	Greenway or Court Herbert Vein 115 to 130
Rosy Vein 18	Rosy Vein 24	Rosy Vein 25½		Jenkin or Morris Vein 44 to 54	Tir Edmond Vein 25
Fiery Vein 36	Fiery Vein	Fiery Vein 44		Six Feet Vein 12 to 20	Graigola Vein about 25
Golden Vein 34		Golden Vein		Three Feet Vein 38 to 49	Upper Maesmelyn Vein 53
Bushy Vein				Two Feet Vein	Lower Maesmelyn Vein

Digitized by Google

Returning to the seams in and below the Pennant Series we find that the Hughes Vein has been extensively worked from Swansea to the shores of the Loughor Estuary, though the other veins which belong to the Hughes Group have been touched here and there only. The mass of Pennant rock, which lies below the Hughes Group, contains the Cuckoo Vein, which has been proved near Cockett, but seems to be of secondary importance. At the base of this rock the Penlan Vein has been worked at intervals from near Dunvant to Penclawdd. Eastwards it runs near Hendre-foilan, but is then lost to view under the great mass of gravel of Sketty and Swansea; there is reason to believe, however, that it corresponds with the Dyvatty Vein,* and is therefore, the nearest equivalent we can find to the Rhondda No. 2 Seam. Mr. Strahan.

The Penlan Vein forms the highest of what are known as the Dunvant Veins. Of these the most persistent are, in descending order, the Penclawdd Big Vein (the most important), the Glammant and the Gleilyd, while a fifth, known as the Rock Vein, exists westward only of Dunvant. The Dunvant group is associated with massive sandstones, the Penclawdd Vein especially having so strong a rock above and below that it crops out along the top of a strike-hill and not along the bottom of a strike-valley as was the case with the Hughes and others. These massive sandstones no doubt correspond to the Llynfi rock,† which is associated further east with the Tormynydd Vein.

The Dunvant Veins crop out close to the station of that name and run thence to the sea near Penclawdd, their position being marked by numerous old, as well as recent, crop-workings. Their position under the gravel of Sketty and Swansea has never been ascertained, nor indeed in any part of Swansea Bay except in the shore of Baglan Bay.

From the Dunvant rocks downwards the Coal Measures consist chiefly of shale—a fact which has contributed to the plication, and which renders the unravelling of the structure extremely difficult. One well-marked group of seams traverses the whole peninsula from Clyne to Glan-Morlais; it includes the following seams in descending order:—The Frog Lane, the Big or Six-Feet, the Yankee, the Four-Feet and the Three-Feet, the thickness of measures between the Frog Lane and Three-Feet Veins amounting to 119 yards. The coals of the Glan-Morlais group are highly bituminous, and are now worked at and east of Glan-Morlais. In Clyne Wood where they were worked a few years ago they are said to have been too soft to be of much value.

The sharp folding which has been alluded to as occurring in the lower measures affects the Glan-Morlais group. Though the outcrops are regular from Glan-Morlais for about a mile, they become untraceable near Pen-llwyn-Robert, and the reason is apparent in the workings of the Morlais Vale Colliery, where the veins have been thrown into a series of steep east and west folds. Similar folding is seen between Killay and Mumbles Road Stations.

* *Summary of Progress* for 1900, pp. 93, 94.

† *Summary of Progress* for 1900, p. 94.

Digitized by Google

Mr. Strahan. Some distance below the Glan-Morlais group we come to the Farm Vein which has been worked north and north-west of Wern-ffrwd, and is said to be 3 feet 6 inches thick; and the Lynch Rider and Lynch Vein, which is said to be 2 feet 6 inches thick. These were worked a few years ago at Wern-ffrwd, and westward from that place the outcrops are marked by continuous old workings for about a mile, the dip being always high and sometimes reaching verticality. These veins are not continuously traceable across the peninsula, for the strata are intensely squeezed and the outcrops have not the regularity which characterise those of the Pennant Measures. In some places, as happens with the Farm and Lynch Veins near Rallt, two outcrops approach so closely that it is evident that many strata have been squeezed out. Compensation is found close by where the outcrops diverge to more than their normal distance, the extra intervening space in such a case being filled up by plications.

The Lynch Vein is the lowest known seam in Gower. It is succeeded downwards by thick shales with an occasional bed of sandstone, but it is not till we have travelled 500 yards south from the Lynch Vein that we see any noteworthy outcrops of the harder rock. These form a long strike ridge on which Llan-Elen stands, and run along the northern margin of Clyne Common to near Clyne Castle. They have shared, however, in the plication, and both in Clyne Park and along the valley north of it they have been doubled up into a series of sharp synclines and anticlines, a fact which combined with the scarcity of sections makes it impossible to trace their outcrop across the peninsula with precision. These sandstones we take as the top of the Millstone Grit, but it should be understood that the separation of the Coal Measures from the Millstone Grit is purely arbitrary. It is founded neither on palæontological evidence nor on any marked lithological distinction, but is adopted to bring the sequence in Gower into accordance with the sequence elsewhere. That the grits of the Millstone Grit are represented by the shales in Gower is certain; but by how much of them is doubtful. The Llan-Elen sandstones form a convenient horizon for mapping purposes, and not improbably represent the Farewell Rock of other regions.

The coals of the region described above are all bituminous, though the measures, from the Penlan Vein downwards, correspond to the measures of the North Crop, in which all the seams are anthracitic.

A number of normal north and south faults cut across the east and west folds of Gower. They can rarely be traced far, though locally their throw may be large. The Dunvant Fault, for example, though large at Dunvant, is non-existent at Bishwell, though it may turn westwards and join the Alltwen Fault. Several faults have been proved in the Penclawdd Vein near Killan-fawr, the largest being a downthrow west of 99 yards. These faults break through the crop of the Hughes Vein also, and one of them has been proved in the Four-Feet, but it is questionable

Digitized by Google

whether they can be identified near Loughor. In that neighbourhood three faults are known to exist; one was crossed in the Mountain Colliery referred to above; a second was proved in the Pengrys Pit, and is estimated to be a downthrow west, of 120 yards, from a consideration of the difference of level of the Four-Feet Vein at Broad Oak and Loughor Upper Town; the third is a downthrow east, reputed to amount to 200 yards, which has been touched under the estuary of the Loughor above Loughor Bridge. This is approximately in line with a fault which cuts all the outcrops from the Hughes to the Gleilyd near Berth Llwyd in Gower, but which is a downthrow west. Of others mention may be made of a fault of 120 yards downthrow west, which has been traced from the Penlan Vein at Trinity Church in Penclawdd to the Big Vein near Glan-Morlais Station. In the Llanelly District the principal north and south faults are the Bryn-Serfyll and the Box Bar Fault, both large downthrows to the east. Mr. Strahan.

TRIAS.

The occurrence of Triassic outliers in Gower has long been anticipated,* but not proved until the past year. The anticipation was founded on the existence of a high level plane apparently of marine denudation, sufficiently obvious to the eye when on a level with it, but especially significant when it is realised that it is composed of highly inclined strata of widely different hardness. Many of the veins, moreover, in the limestone had served as conduits for a red stain, while some contained hæmatite, strong evidence of the former existence of Trias not far overhead. Two occurrences of Trias may now be recorded. At Port Eynon an excavation from which shale was raised for the manufacture of paint has disclosed the edge of a massive Triassic conglomerate, which is described by Mr. Wilkinson as follows:—"The conglomerate rests upon almost vertical black shales belonging to the Bishopston Series and lower part of the Millstone Grit. The matrix is pinkish, and in places of a soft clayey nature; the boulders, which are large and abundant, have been derived chiefly from the Carboniferous Limestone, but include many of black and grey chert, derived no doubt from the shales above the limestone."

The other locality referred to lies some distance farther west. The Trias occurs in a swallow-hole or chasm in the limestone, due to collapse along a line of fault. The rock is a deep-red sandy marl, variegated with spots and streaks of green. In it are imbedded masses of limestone and calcspar fallen from the walls of the chasm, which obviously was open and undergoing enlargement in Triassic times. A somewhat similar case was recorded in the *Summary of Progress* for 1898, p. 134.

RAISED BEACH.

The sequence of deposits associated with the Raised Beach of Gower was described in the *Summary of Progress* for 1899, pp. 154, 155. During the past year the same sequence has been

* See Tawney, *Proc. Bristol Nat. Soc.*, Ser. 2, vol. i, p. 165.

Digitized by Google

Mr. Strahan. observed by Mr. Wilkinson on the north coast between Burry Holms and Hills Tor and on the south side of the Worms Head. Here the beach is little below the 50 feet contour, but between Tears Point and Mewslade Bay it is not more than 15 or 20 feet above sea-level, while from Overton Mere to Oxwich Point it lies just above high-water mark.

GLACIAL.

In an examination of the Glacial phenomena of South Wales, the fact that the Brecknock Beacons formed an ice-parting claimed early attention. Though boulders derived from them are distributed freely over parts of Monmouthshire and Glamorganshire, no rocks from farther north found their way across them. Later on a similar observation was made with respect to the Pennant escarpment which culminates in Carn Mosyn at a height of nearly 2,000 feet. From this also boulders were carried in abundance southwards, though none succeeded in crossing it from the north. The escarpment, together with others, therefore played the part of a subsidiary ice-parting, for it by no means formed the northern limit of glacial action, but merely acted as a local obstacle to the southward movement of the Brecknock ice, at the same time that it gave birth to a small flow of its own. Recent work tends to show that the Brecknock Beacons themselves played a similar part with reference to the glacial system of Wales, though on a larger scale.

The range formed by the Brecknock Beacons, the Carmarthen Fans, and the Black Mountains, diminishes in height westwards, until in the region now under examination the escarpments of Lower Carboniferous Rocks and Old Red Sandstone rarely exceed 600 feet in height, while they are traversed by valleys or cols descending to 400 or 500 feet above the sea, and one valley, followed by the railway, descending to 200 feet. In the same region the valley of the Carmarthen Towy takes its course along the northern side of the range, and at no great distance from it, the bottom of the valley being about 60 or 70 feet above the sea. Notwithstanding this difference in level, Mr. Cantrill has found repeated proof both in the direction of the striæ and in the dispersal of boulders, that the ice mounted the escarpment and passed over it southwards.

The ice which occupied the Towy Valley travelled down that valley westwards as a whole, and the fact that a part was driven across the escarpment southwards can be explained only on the supposition that the valley was filled to overflowing, and that a region in Central Wales, of which the glacial phenomena are as yet unknown, was buried under ice of great thickness.

Mr. Cantrill. The observations upon which these conclusions are founded have been made chiefly by Mr. Cantrill. He reports as follows:—The ice-movement was parallel to the main features with a tendency to swing southwards when approaching a gap in the Tilestone ridge; thus the striæ near Cilmaenllwyd point S. 52° W., but nearer to the gap of the Cennen Valley they change gradually to

Digitized by Google

S. 20° W.. Moreover much Silurian detritus occurs in the Boulder Clay which overspreads the outcrop of the Old Red Sandstone in the Cennen Valley, though very few boulders of the Old Red Sandstone can be found on the Silurian outcrop. Lastly, a limestone quarry half-a-mile south of Ffairfach shows the edges of the beds turned towards the south, as though by the passage of ice up the valley. It is clear, therefore, that the main movement was from the north-east, and was due to a great accumulation of ice in Central Wales. Mr. Cantrill.

Evidence of similar movement has been obtained by Mr. Cantrill on the Millstone Grit scarp between the Cennen and Loughor Valley, near Llandybie. Careg-Dwfan, 926 feet in height, has been striated by ice, which crossed it from the north-east, on its way to the Loughor Valley. A flow passed also through the Millstone Grit gap at Llandybie, but was deflected by the local configuration to a direction S. 15° E. The high Pennant scarp, south of the Amman Valley, was over-ridden by ice forced southwards, a fact which explains the occurrence of many Old Red Sandstone and limestone boulders in Cwm Cathan, and of an abundance of fragments of Silurian mudstones in Nant Ffin, at a distance of six or seven miles from the nearest Silurian outcrop.

Mr. Cantrill notes also the occurrence of conspicuous masses of gravels of late glacial age, where the Cennen leaves the strike-valley west of Trapp, and debouches upon the broad north and south valley followed by the railway. These gravels have been derived from the Cennen Valley, but take a moundy form which is not observable in river-terraces formed under existing conditions. They were probably the work of effluents from the ice-sheet, during a late period in its existence. From the fact that they extend southwards, it seems probable that the effluents took that direction, and not the northward course now followed by the Cennen.

To the west of Swansea there is a great development of mounds and ridges of gravel. The deposit covers the whole of the slopes extending from the shore to the foot of the Pennant scarp, nor has its base ever been reached, either in the lower part of Swansea or near Sketty. Clyne river has cut through it to the Coal Measures, and the rock crops out in the fore-shore at Liliput, in both cases near the western limit of the gravel tract. Part of the deposit is a tumultuous assemblage of well-rounded boulders up to 6 or 8 inches in length, imbedded in a gravelly matrix, but the deeper sections usually reveal roughly stratified sand and gravel; in an old brick-pit near Clyne Colliery the gravel is associated with a deposit consisting of alternations of fine sand and laminated loam, such a sediment as would be formed in tranquil water into which sediment was being poured rather copiously. The gravels have been thrown down everywhere in hummocks and ridges, enclosing hollows, and the character of the laminated deposit suggests that it was laid down in one of these hollows; glacial conditions still prevailed, however, for the loam was subsequently buried under a few feet of Boulder Clay. Mr. Strahan.

Digitized by Google

Mr. Strahan. The boulders of the Swansea and Sketty gravels include, in order of abundance, Coal Measure grits, white pebbly grits, and Old Red Sandstone. That the material was derived from the North Crop, by way of the Swansea Valley, seems certain, but the source of the pebbly grits is open to doubt. Some much resemble the pebbly Silurian passage-beds, but they have yielded no fossils.

The gravel-ridges generally run parallel to the Pennant escarpment, but a few large hummocks jut out from the hillside in a southerly direction, as, for example, on either side of the valley running down from Cockett to Sketty. Both at Swansea and Llanelly the direction of transport seems to have had a strong westward trend, wherever the local configuration of the ground permitted. The spit of land which projects into the estuary south of Llanelly owes its existence principally to a mound of glacial gravel, and to a shingle-ridge derived from it. A cliff, about 60 feet high, shows a very coarse, roughly stratified gravel with beds of sand, contorted in places. The boulders range up to 2 feet in length and the assemblage resembles that of the Swansea gravel. A bore-hole put down on the eastern slope of the mound is said to have passed through 120 yards of loose material before reaching solid rock. Several other gravel-mounds project through the alluvium between Llanelly and Loughor Bridge, in a tract on which the mining information has not yet been collected.

Striations on rock-in-place are scarce everywhere near the southern margin of glaciation. The southernmost striæ observed during the past year occur in a quarry at Allt, near Llangennech (Sheet 230). They range W. 35° S., and point clearly to the ice having had a more westerly trend than has the Loughor River. None have been found in any part of Gower, though striated boulders are common.

Mr. Tiddeman. A long crescentic ridge, on the top of an east and west hill on Welsh Moor, is described by Mr. Tiddeman as looking like the terminal mark of a glacier or ice-sheet, momentarily advancing during its retreat northwards. The east and west arrangement of mounds of gravel and Boulder Clay, between Killay and Fairwood suggest the same kind of action. But, on the other hand, he considers the gravel-mounds at the confluence of several streams above Bishopston to have more probably been due to the action of glacial streams on the material brought by the ice-sheet.

Mr. Wilkinson. As throwing light on the direction of transport Mr. Wilkinson notes that boulders of Old Red Sandstone are far more numerous on the south than on the north sides of the hills formed by that rock. To this may be added the fact that Coal Measure detritus abounds in the Drift far to the south of the base of that formation.

Mr. Strahan and Mr. Wilkinson. Some of the Drift, and especially the lowest part of it, is of strictly local origin. Thus in the fine section of Rhossili Bay there rests immediately upon the limestone an accumulation composed almost wholly of limestone-fragments, while above this again, with a fairly definite base, comes a mass of gravel in

Digitized by Google

which well-rounded far-travelled boulders of Coal Measures, Old Red Sandstone, &c., predominate. Again, in the centre of the bay the cliff is composed of boulders derived from the hill-slope above, but close by, to the north and south, the Drift of more distant origin comes in on top of the purely local material. It is worthy of note that this mass of local Drift lies just opposite a hollow in the hillside. Mr. Strahan and Mr. Wilkinson.

Several large domes of stratified sand and gravel have been noted by Mr. Wilkinson. From the general gravelly character of the Boulder Clay, especially near the surface, there is always much difficulty in separating it from the sand and gravel.

ECONOMICS.

The ground surveyed during the past year is almost wholly pasture, but little more land on each farm being kept under the plough than is necessary for the wants of the farmer. The soil yielded by the Glacial Drift, whether of the type distinguished as "Boulder Clay," or that as "Sand and Gravel," may all be classed as gravelly. There is a considerable area of salt marsh in the estuary of the Loughor which is valuable as pasture, and the gathering of cockles in the tidal sands beyond constitutes an important industry. Parts of the Millstone Grit and Pennant Grit outcrops consist of mountain land, but such tracts are far less extensive than in the central parts of the coalfield. The steeper slopes of the hills are utilised for the growth of pit timber. Mr. Strahan.

Among economic products apart from coal may be mentioned the Carboniferous Limestone burnt at Llandybie and Oystermouth (both white and so called "Black Lias" limestone), and the Llandilo Limestone at Llandilo. Building-stone is obtained chiefly from the Pennant Grit, at Pen-y-Fan, Dunvant, and Cockett; and paving-stone from a quarry between Llanelly and Felin Foel. The Tilestones were formerly quarried for roofing. Clay for puddling is dug on the foreshore at Swansea, and rottenstone is worked to a small extent in the Upper Limestone Shales of the North Crop, but a more important industry consists in the quarrying of the more purely siliceous bands in the Millstone Grit at Carn Bica for the manufacture of fire-bricks at the Bynea Brick Works near Llanelly. "Plastic clay," an impalpably fine siliceous sand, is worked by level near the same place. Millstone Grit shale, stained purple or red by infiltration from Trias, used to be ground up and made into paint near Port Eynon.

4. Examination of New Railway and other Sections.

NOTES ON A NEW RAILWAY IN COURSE OF CONSTRUCTION BETWEEN AXMINSTER AND LYME REGIS.

BY H. B. WOODWARD.

The railway, which is a "light" one, starts from the main line of the London and South-Western Railway a little south-west of Axminster station, and at an elevation of about ninety feet.

Digitized by Google

Mr. Woodward.

It follows a serpentine course to Combe Pyne Hill, attaining an elevation of about 415 feet, and after passing through Uplyme, terminates to the north-west of Lyme Regis at an elevation of about 240 feet.

In a shallow cutting by the main line, valley gravel was seen to rest irregularly on the Keuper Marl. The gravel consists for the most part of rough flint and chert stones, with pebbles of quartz and dark grit. Stones occur some way down in the Keuper Marl, having probably descended through cracks formed in dry weather; but here and farther on there are evidences of considerable soil movements and small landslips which have led to the incorporation of gravel with red marl.

Thus by the orchard south-west of Shools Farm there was an interesting section of the valley drift, a good deal disturbed, and showing gravel with patches and bands of red Keuper Marl, which in the re-arranged condition showed little or no variegation. (Fig. 1.)

Below the railway by Abbey Gate Bridge the road-cutting showed pockets of gravel in the red and variegated Keuper Marl,

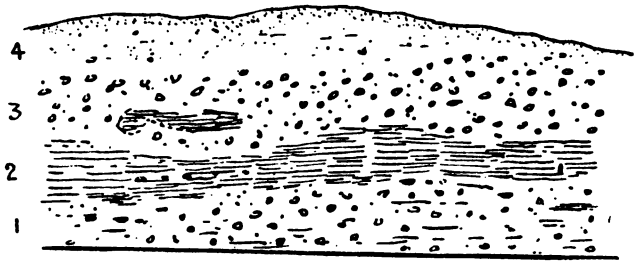


Fig. 1. Section south-west of Shools Farm near Axminster.

4. Soil and sandy loam.
3. Gravel with patch of red marl.
2. Red marl with stones.
1. Clayey gravel.

} 8 to 9 feet.

a feature perhaps due to the effects of subterranean stream erosion.

Southwards a broad patch of gravel extends to near Bean Close Coppice, where grey and greenish marls appear above the red and variegated Keuper Marls, forming the passage-beds into the Rhætic formation.

By the bend of the railway, north-east of Great Trill, a striking section was displayed of inclined and banded red and variegated Keuper Marls with overlying and partially interbedded gravel—an arrangement evidently due to the slipping of a mass of ground, and during the process some slight faults were produced in the Keuper Marls, which have a north-westerly dip. The features occur on the spur of a hill. (Figs. 2 and 3.)

Further south, near South Ground Linhay, there is a cutting in the Keuper Marls, comprising red and variegated marls and a conspicuous band of hard pale marl, overlain by grey, green, and red marls, and higher up by grey marls.

Digitized by Google

These strata were hollowed out on the eastern bank of the cutting to a depth of 20 to 25 feet, nearly to the level of the railway, the cutting being about 30 feet deep, and in the hollow was a mass of sand and chert detritus derived from the Upper Greensand. On the western bank, towards the valley, where the cutting is lower (18 to 20 feet deep) there was a wider spread of Greensand *débris*, and the Keuper Marls showed evidence of slight anticlinal disturbance, which may have been due to the breaking away of a mass of Greensand from the uplands of Trinity Hill on the east. (Figs. 4 and 5.) Mr. Woodward.

North side.

South side.

Figs. 2 and 3. Railway-cutting north-east of Great Trill near Axminster.
2. Gravel.
1. Keuper. Red marl with bands of green marl. } Up to 12 feet.

In following the railway towards Newlands Coppice the cutting (in course of construction) showed pale and dark grey marls, with irregular patches of chert detritus. By the Coppice there was a trace of black clay, evidently a portion of the Rhætic (*Avicula-contorta*) Shales, as the soil above contained fragments of White Lias.

To the south-east of Newlands Farm there is a long cutting from 10 to 25 feet deep in red, brown, grey, and greenish sands of the Upper Greensand, capped most irregularly by chert detritus. Irregular broken bands of chert, moreover, appeared at various levels. Here unquestionably the Upper Greensand, which comprises sands with bands of chert of varying thickness, had been disintegrated by the action of the weather, and the mass had been affected by a certain amount of land-slipping. Further on by Hartgrove Farm there was much rough chert detritus resting on the Greensand.

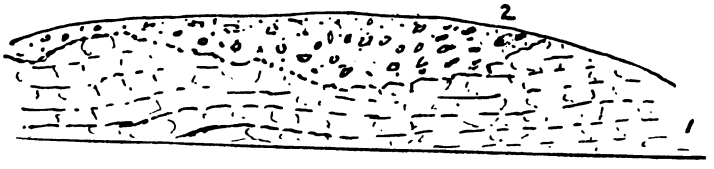
A different deposit was exposed to the south of Hartgrove Farm, being reddish brown loamy clay with angular and unworn flints, 10 or 12 feet thick. This may belong to the beds noted further on by Combe Pyne station. In the intermediate ground, comprising moorland and plantations, the Upper Greensand was exposed in places, but the land was for the most part covered with angular chert detritus, or "run of the hill" from the high ground of Shapwick Hill on the east.

Digitized by Google

Mr Woodward.

East side.

West side.



Figs. 4 and 5. Sections near South Ground Linhay, south of Axminster.
2. *Débris* of Upper Greensand—sand and chert.
1. Red and variegated Keuper Marl with band of hard pale marl.

Where the railway cuts the northern part of Combe Pyne Hill, a cutting (not completed) showed 3 or 4 feet of loamy flint drift resting on 5 or 6 feet of irregular and disturbed pipe-clay, whitish and pinkish in colour, and with black coatings on the joints, in irregular pockets, and on imbedded stones of flint and quartz. The black coating was determined by Dr. Pollard to be manganese-ore. The stones occurred in a band, the quartz pebbles varying in size from that of a pea to $\frac{3}{4}$ inch in diameter.

The appearance of these deposits suggested a possible trace of Bagshot Beds. Quartz pebbles had not been noticed in the plateau-deposits previously met with along the railway.

The suggested age of the beds was confirmed in cuttings further south, where unctuous white clay and white sand with flints were exposed. The beds evidently formed part of the series seen on the northern part of Combe Pyne Hill, but they were much concealed beneath a downwash of angular flint and chert detritus.

The clean white sand had every appearance of Bagshot sand, and on submitting a sample to my colleague, Mr. H. H. Thomas, he determined the ingredients as noted in the accompanying statement. The minerals are suggestive of derivation from a granitic area.

NOTES ON THE BAGSHOT SAND, FROM COMBE PYNE, IN DEVONSHIRE.
BY H. H. THOMAS.

This sand, which is very fine, is of a dirty white to a pale yellow colour, and is gritty between the fingers.

Large grains are rare, and there is a complete absence of calcareous matter in the form of carbonates

Digitized by Google

The following are the chief minerals which constitute the heavy residue—that part of the sand with a specific gravity greater than 2·9 :— Mr. Thomas.

Rutile. This mineral, which is perhaps the most prevalent of those in the heavy residue, occurs for the most part in rounded prisms of an amber colour. Polysynthetic twinning is common, the striæ making about 25° with the long axis. Geniculate twins also occur, following the same law of twinning as the above ; the axes of the individuals being inclined to one another at near 65°.

Zircon. In rounded prisms and grains with fresh fracture, containing many colourless inclusions arranged parallel to the prism faces and to the pyramid (111).

Tourmaline. This mineral occurs in dark brown pleochroic prisms, which in some cases show the outlines of the simple rhombohedra. The grains have not been rounded to any great extent.

Leucoxene. In yellow, green, and white, almost opaque grains, all more or less rounded ; in some cases there is evidence of an unaltered dark core, probably *Ilmenite.*

Micas. A white mica occurs in minute flakes.

Of the lighter residue, Quartz and Felspar are the main constituents: —

Quartz. In small angular grains, full of minute inclusions. Very few grains are rounded, and there is no evidence of secondary growth. As might be expected, this mineral forms the main bulk of the sand.

Felspar. The only felspar noticed was orthoclase ; it exists in rectangular cleavage fragments, all more or less decomposed, in some cases so much so as to render them almost opaque.

This mineral, although not so plentiful as the quartz, occurs in fair quantity.

Round dark grains were found to consist of an earthy material, giving the reactions of manganese.

These grains probably consist of carbonaceous matter (? wood), associated with an earthy oxide of manganese.

Additional evidence in support of the Bagshot age of the beds was obtained in the long cutting east of Combe Pyne Station. This cutting is 35 feet deep in places, and although unfinished it showed a series of white, red and mottled stony clays and grey loam overlaid by rough flint and chert gravel. The clays had a marked inclination towards the east, but the dip was obscured in the upper part of the section, probably owing to the fact that the beds have suffered from prolonged sub-aërial action. The character of the deposits, and the remarkable inclination of the layers reminded me at once of the white and coloured clays and sands and coarse gravels which border the Bovey Basin at Wolborough and other places near Newton Abbot—beds which I had many years ago regarded as equivalent to the plateau drifts of Haldon,* and which have recently been shown by Mr. Reid to be for the most part of Bagshot age.† (Fig. 6.) Mr. Woodward.

---

* *Quart. Journ. Geol. Soc.*, vol. xxxii., p. 234.

† *Ann. Rep. Geol. Survey* for 1895 ; and *Quart. Journ. Geol. Soc.*, vol. liv., p. 234.

Digitized by Google

Mr. Woodward.

It is noteworthy that in the last *Summary of Progress* (for 1900, p. 122) Mr. Reid remarked that "Though the mapping of the Hampshire Basin has now been completed, it is probable that a chain of outliers of the Bagshot river-gravels will connect the Eocene of Dorset with that of Bovey Tracey in Devon—indeed, several outliers of this gravel have already been mapped."

Thus outliers have been traced as far west as the neighbourhood of Maiden Newton, in Dorsetshire, by Mr. L. W. Hinxman and Mr. E. E. L. Dixon.*

Fig. 6. Section east of Combe Pyne Station.
Bagshot Beds. White and red stony clays and gravels.

The foregoing remarks by Mr. Reid were not present in my mind while examining the cutting at Combe Pyne; it was therefore an additional satisfaction to read them afterwards. During the years 1873 and 1874, Mr. Ussher and myself, and in 1874 Mr. Reid also, were engaged in re-surveying the country round Honiton, Axminster, and Lyme Regis, and we were then perplexed to account for the plateau deposits. Some were evidently local, but in other tracts there were foreign materials, large pebbles of quartz, and quartzite, for which it was difficult to account. I was led to treat as probably Boulder Clay, a mixed deposit found at Yarcombe, between Honiton and Chard.† It seems quite likely now that this deposit, which comprised greenish-yellow clay, reddish-brown and pale-coloured sand, and gravel with quartz and quartzite, as well as flint and chert, may belong to the Bagshot series.

Leaving Combe Pyne Hill, the new railway extends eastwards towards Uplyme, along a scarp of Upper Greensand just below the Chalk. The chert beds of the Greensand here, as elsewhere, were of somewhat irregular occurrence in the sands, and where shattered by frost, they have formed a kind of angular drift on the slopes.

Beyond the viaduct which crosses the deep valley south of Cannington Farm, the Greensand was well exposed with little detritus on top, but further on below the steep scarp of Horseman's Hill, which is formed by the chert beds, the ground was covered with cherty *débris*.

West of the Uplyme road the chert and flint detritus was seen to rest most irregularly on grey and greenish sand of the Upper Greensand, owing chiefly to slips. Here the gravel contained a good deal of very red clay, with irregular brown and blackish

* *Summary of Progress* for 1898, p. 145; for 1900, p. 122.
† *Geol. Mag.*, 1874, p. 335.

Digitized by Google

layers, but it was less distinctly stratified than that in the lower part of the Combe Pyne cutting. Mr. Woodward.

Towards Lyme Regis station a somewhat similar section of 9 or 10 feet of gravel was seen above dark green sand belonging to the Upper Greensand.

FURTHER NOTES ON THE CUTTINGS ALONG THE SOUTH WALES DIRECT RAILWAY.

BY H. B. WOODWARD.

Particulars of the strata exposed along the cuttings of this railway were given in the *Summary of Progress* for 1898, pp. 188-192, from notes furnished by Mr. A. Strahan and myself. During the autumn I re-examined the cuttings from Wootton Bassett to Alderton. In the upper part of the cutting west of Hunt Mill Lane, Wootton Bassett, a band of coarse oolite belonging to the Corallian was exposed below the rubbly coral limestones and clays which form the upper part of that formation. No evidence of Lower Calcareous Grit was discernible, and it is possible that the beds are faulted against the Oxford Clay, but as the cutting had been sloped, precise evidence was not obtained. Onwards to near Hullavington the line has been nearly completed and all the cuttings have been sloped. Scattered flints (some of Eolithic type) are to be found above the Oxford Clay west of Brinkworth, and they are strewn over the ground to the north on Ramps Hill and beyond. These flints are gathered from the fields for road-mending, and they sometimes occur in sufficient mass for the opening of a shallow gravel-pit.

The cutting west of Bradfield Farm, Hullavington, had been considerably deepened since my former visit, and it exhibited an interesting section of Cornbrash resting on inclined layers of Forest Marble as shown in the accompanying diagram. (Fig. 7).

While the Cornbrash oversteps the inclined layers of Forest Marble clay and shale, these beds of Forest Marble themselves rest irregularly on a lower portion of the formation, a sandy division: so that there is evidence of a double (minor) unconformity—due partly to current-bedding and local erosion. At the top of the Forest Marble clay there is a thin oyster-bed made up of variable forms of *Ostrea Sowerbyi*. This is a feature of some interest. Oyster-beds occur here and there throughout the Jurassic system, but this is the most prominent bed that has been noticed in the Forest Marble of the west of England.

During an excursion made in May 1901 by the Geologists' Association,* the cutting was examined, and attention was then drawn by Mr. W. Whitaker to the fact that Cornbrash here lies on different divisions of the Forest Marble.

Sections of equally noteworthy character were observed by myself in cuttings along the Midland and South-western Junction Railway near Cirencester.†

* *Proc. Geol. Assoc.*, vol. xvii., p. 144.

† *Jurassic Rocks of Britain*, vol. iv., p. 366.

Digitized by Google

Mr. Woodward.

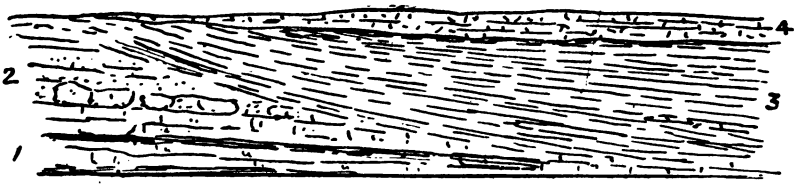


Fig. 7. Cutting west of Bradfield Farm, Hullavington.
4. Cornbrash. 2. Sands, sandstone and shaly beds.
3. Shales with thin calcareous grit. 1. Limestones, shales and clays.

It is not easy to build up the sequence of Forest Marble, and here and there small faults affect the strata and their amount and throw cannot always be definitely ascertained.

The following appears to be the succession between Hullavington and Alderton:—

Cornbrash.

Forest Marble.	Oyster Bed with *Ostrea Sowerbyi* : - - -	8 in. to 10 in.
	Clays with thin layers of calcareous grit with track-markings - - - - - -	20 ft.
	Shales and limestones - - - - - -	5 „
	Sands and hard calcareous sandstones -	20 „
	Oolitic and shelly and gritty limestones, with lignite and shales—false-bedded—and to some extent replacing one another - -	35 to 50 „
	Blue clay with occasional bands of limestone	25 „

Great Oolite. Pale oolite. Seen to depth of 18 feet at Alderton.

The sands and sandstones are approximately equivalent to the Hinton Sand and Sandstone of William Smith. They exhibit large doggers with the well-known pot-lid structure. The limestones are manifestly impersistent.

REPORT ON THE EXAMINATION OF THE SECTIONS AT THE RESERVOIRS AND ALONG THE COURSE OF THE AQUEDUCT OF THE BIRMINGHAM CORPORATION WATERWORKS, RHAYADER TO FRANKLEY, 1901.

BY T. C. CANTRILL.

During the month of August about a fortnight was devoted to examining the sections at the reservoirs west of Rhayader and along the course of the aqueduct thence to Frankley near Birmingham.

The Silurian sequence of Rhayader has been described in great detail by Mr. H. Lapworth.* According to him the reservoirs in the Elan and Claerwen valleys are situated chiefly on the slates which form the Dyffryn Flag subdivision of the Gwastaden Group or Lower Llandovery rocks of the district. There are many natural sections and the works have opened up others.

* *Quart. Journ. Geol. Soc.*, vol. lvi (1900), p. 67.

Digitized by Google

Mr. Cantrill.

The dam of the Dolymynach reservoir is being constructed on a grit bed underlying cleaved shales and forming a compressed anticline and syncline trending north-east and south-west, and traversed by two well-marked thrust-planes along which movement has taken place from the north-west. This grit appears to be part of the Cerig Gwynion Grits which immediately underlie the Dyffryn Flags and form the base of the local Lower Llandovery.

The aqueduct leaves the Carreg-ddu reservoir by a tunnel carried through the Dyffryn Flags of Craig-y-Foel, across the well-marked Abernant Fault and into the Caban Group or Upper Llandovery.

East of Elan Village the pipe-track passes into the Rhayader Pale Shales or Tarannon Beds, and continues in this subdivision as far as the western side of the Wye Valley south of Rhayader. It then descends the sequence into the Gwastaden or Lower Llandovery, the Caban Group having apparently been overlapped. The Gwastaden Group consists of various shaly, flaggy, and conglomeratic beds subdivided into several zones characterised by peculiar graptolites. The pipe-track gradually crosses these subdivisions and passes off the lowest at Gaufron, 2 miles east of Rhayader. It then enters the district occupied by the dark shales with grit-bands believed by Mr. Lapworth to be of Bala age. Of this district he remarks* that certain dark seams in the arenaceous rocks yield *Diplograptus foliaceus*, Murch., and other graptolites. Beyond this district of Nantmel we leave the ground examined by Mr. Lapworth.

East of the river Clywedog cleaved brown shales are introduced by a bold feature which crosses the district in such a way as to suggest that it is due to newer beds markedly unconformable to or faulted against the Ordovician, and the aqueduct is carried through this feature by the "Penybont Tunnel" into the Ithon Valley. The tip at the western end of the tunnel in Gwgan Hall Wood is composed of dark flags and shale, with pieces of conglomeratic rock; no fossils were observed, and there was nothing to show the exact source of the *débris*. Probably most if not all of this material came from the Ordovician beds. Surface exposures along the course of the tunnel show that the newer strata dip on the average in an easterly direction. These beds are shown on the Geological Survey map [old series, Sheet 56] as belonging to the Wenlock Series. But the brown and grey shales and sandstones forming the tip (presumably from the eastern part of the tunnel) south of Bryn-hyferth (= Bryn-rhyfedd on the old series map) being full of graptolites, some of these were collected by Prof. Watts and myself, and have been identified by Miss Ethel M. R. Wood, of Birmingham University. She reports as follows:—

---

* *Op. cit.*, p. 96

Digitized by Google

Mr. Cantrill.

"On tip at Bryn-hyferth Farm [Six inch map, Radnor, 16 S.E.], 1¼ miles north-west of Penybont Village, graptolites occur in great abundance on thin splintery brown shales. I have identified *Monograptus colonus*, Barr., *M. Nilssoni*, Barr., *M. bohemicus*, Barr., *Retiolites spinosus*, Wood. These graptolites are characteristic of the *M. Nilssoni* zone in the L. Ludlow shales, which occurs above the *M. vulgaris* zone and below that of *M. scanicus*. This zone is quite similar, both lithologically and palæontologically, to that in the Builth District, and also agrees closely with the same zone in the Long Mountain.

"In somewhat more flaggy beds at the same locality occur *M. colonus* in abundance, associated with one or two fragments of *M. bohemicus* and *M. Nilssoni*. These belong to the same zone as the above."

It thus appears that the Silurian beds here must be referred to the Lower Ludlow Shales and not to the Wenlock Series.

Roadside exposures at Tre-grugyn, at the supposed junction of the Ludlow and Wenlock north of Llanfihangel Rhyd Ithon yield graptolites, among which Miss Wood has identified *Retiolites spinosus*, and remarks that she has not found this hitherto outside the *M. Nilssoni* zone in the Lower Ludlow. This, together with the evidence of the graptolites from the Penybont Tunnel, makes it doubtful whether there is any foundation for the position of the Lower Ludlow base here.

Numerous exposures of the Ludlow beds occur thence to beyond Knighton. The Old Red Sandstone west of Brampton Bryan where crossed by the pipe-track is overspread with gravel, and the solid rock does not seem to have been exposed. East of Brampton Bryan gravel extends as far as Walford, beyond which the Silurian beds are more of the classical Shropshire type, and contain various bands of limestone. The Aymestry Limestone forms some fine cliffs on the west side of the Teme south of Downton. Some of the beds are full of *Pentamerus Knightii*. Beyond this point the pipe-track closely follows the top of the Aymestry Limestone. The Passage-beds into the Old Red at Ludlow do not seem to have been exposed, and east of the river Teme the pipe-track enters and continues for some distance in the lower beds of the Old Red Sandstone. It crosses the Ludlow series of Caynham Camp and revealed below the Aymestry Limestone some thickness of shales not shown on the map. (Sheet 55.)

The "Studley Tunnel" under the southern promontory of the Titterstone Clee Hill commences north of the village of Hope Baggot, in the Old Red Sandstone. From information supplied by Mr. J. McKie, the engineer in charge, it appears that the beds at first encountered consist of the ordinary red and green marls and soft shaly red sandstone; but at about 1400 feet the heading passed into harder beds of pebbly light-red coarse sandstone, the pebbles being chiefly of vein-quartz. This bed had not been pierced at the time of my visit. There is little doubt that this represents the Upper Old Red Sandstone, or at least the highest Brownstones of other districts, while the marls with cornstones which occupy the lower horizons and extend from Ludlow to the Wyre Forest Coalfield belong to the Lower Old Red. The eastern heading of the Tunnel was at the time of my

Digitized by Google

visit about 1100 feet in; it had passed from Old Red through the Carboniferous Limestone into Millstone Grit and possibly Coal Measures—various yellow and grey grit *débris*, together with clods, shales, and fireclays, occurring on the tip. If these latter belong to the Coal Measures, the lines on the map will need some little adjusting, as the Coal Measures are shown as forming only a capping at the top of the hill where crossed by the line of the tunnel. Mr. Cantrill.

Beyond Studley the aqueduct crosses the broad tract of Lower Old Red, extending from Clee Hill to the Wyre Forest. The Coal Measures of this latter coalfield where crossed by the pipe-track —from Malpass Wood to Hawkbatch Farm on the Severn— appear to consist of two groups: a lower, of variegated marls with yellow and green sandstone, in which the crop of a coal has since been cut through at Silligrove; and a higher group of grey and yellow sandstones with thin pyritous coals and one or more bands of *Spirorbis* limestone. The lower group has some likeness to the Old Hill Marls of South Staffordshire and the Etruria Marls of North Staffordshire; while the higher, as seen at Winwoods and Kingswood, and again at Woodhouse Farm near Button Oak, may represent the Halesowen Sandstones of the former district and the Newcastle-under-Lyme beds of the latter.

The junction of these Coal Measures with the Lower Old Red of Trimpley appears to be either a very sharp overfold or more probably a fault, the Old Red being thrust from the east over the Coal Measures. The lowest beds of the Trimpley anticline appear to be certain flaggy greyish-red beds and yellowish-grey tilestones which crop out at Trimpley Church and Littlegains. From these beds numerous fish-remains were obtained by G. E. Roberts,* who considered them to represent the uppermost Silurian or Passage-beds of other districts.

Beyond the Old Red Sandstone of Trimpley the Trias is entered and extends as far as Hagley, near Stourbridge. The sections call for no particular note. The so-called Lower Permian beds of the South Staffordshire Coalfield were then entered. The rocks consist of red and crimson marls, mottled blue, with some pale-red sandstone and occasional bands of conglomeratic cornstone. The presence of bands of *Spirorbis* limestone in similar beds at Sandwell and Hamstead Colleries on the east side of the coalfield had long been known, but no outcrops in the "Permian" ground to the south had previously been observed. The excavations for the pipe-trench have now exposed outcrops of such limestones at three different points between Hagley and Frankley. The first locality lies 100 yards west of Wassel Grove Lane at Hagley; the second is on the edge of Offmoor Wood, north-north-east of the Fox Inn at Romsley. The third is at the terminal reservoir at Frankley, where the limestone contains the characteristic fossil. From information supplied by Mr. Fred. W. Macaulay,

* *Rocks of Worcestershire*, 1860, Chap. vii.

Digitized by Google

Mr. Cantrill. the engineer in charge, it appears that the limestone outcrop was met with in some excavations for the filter-beds at about 250 yards N. 20° W. from Frankleylodge Farm. The bed was about 1 foot or 1 foot 6 inches thick, the stone being rather rotten and much broken up. The position of this band is not far below the bottom of the "Permian" breccia as drawn on the map (Sheet 54 N.W.); and whether this latter is conformable or not to the red marls and sandstones, there is little doubt that the limestone here is higher than the other two bands, and that there are three distinct bands of *Spirorbis* limestone in these red rocks.

NOTES ON THE GOOLE AND MARSHLAND LIGHT RAILWAY.

BY W. GIBSON.

The Goole and Marshland Light Railway, now under construction, passes over the more elevated portions of the Isle of Axholme, and exposes some good sections of the solid rocks which are rarely to be seen in this part of Lincolnshire.

To the north of Haxey Village a cutting, one mile long and 30 to 40 feet deep, is being excavated in Keuper marls. These consist of red and green sandy marls, containing "skerries" and bands of red sandstone a few inches thick. Fibrous gypsum, in the form of isolated plates or in irregular bands from two inches to four inches thick, is developed throughout. The stratification is irregular, a feature common to the gypsiferous portions of the Keuper marls elsewhere.

The marls are overlain by a warpy silt 3 to 4 feet thick; the junction with the marls is sharp and even, and forms a line of demarcation for nearly the entire length of the section to near Haxey Village, where blown sand forms the surface-deposit. The warpy silt lies close to the 100 feet contour, and has the appearance of being of aqueous and not of æolian origin. If this is correct it implies a certain amount of elevation; but the relation of the warpy silt to the other superficial deposits of the district is not clear.

In making the foundations near the drain north of Haxey Station Mr. M. F. Glover, the engineer in charge of this section, proved sand for over 26 feet. A ferruginous band was passed through six feet below the surface.

Blown sand appears to occupy much of the surface passed over by the line from the north end of the cutting at Haxey to Epworth.

A cutting has just been commenced one half of a mile north-west of Epworth Church. The section exhibits Keuper marls of a very similar type to those of the Haxey cutting, but the bands of gypsum are slightly thicker.

Between Epworth and Crowle Town the line has not been laid out.

Crowle Hill, near Crowle Town, has been partly cut through from the north. Warpy sand 3 to 4 feet thick forms the surface of the section. This rests on Keuper marls containing thin

Digitized by Google

bands of gypsum, like those in the Haxey and Epworth cuttings. The stratification is more evident, and a dip of 15 degrees east can be clearly made out. The north end of the section shows blown sand overlain by the talus from an old quarry through which the line passes. Mr. Gibson.

No sandstones have been met with in any of the sections of sufficient hardness or thickness to form building stones. These evidently occur lower down in the sequence, for in the Reedness boring, which is on the line of strike of Crowle Hill, the sandy marls were 272 feet thick, after which sandstones were met with.*

North of Crowle Hill the line passes over warped land. As shown in the excavations for the telegraph posts the warp lies on peat and is nearly all of artificial origin.

Peat is being extensively dug for litter south of Reedness station. At this spot numerous stumps of trees, several standing erect, are exposed in the excavations for the line and station buildings. They are overlain by a thin layer of warp.

II. PETROGRAPHICAL WORK.

The material forwarded to the Petrographical department in London for examination and report during the year 1901, has to a very large extent been furnished by those areas of the Scottish Highlands which lie to the east and south of the Great Glen, and has consisted, as in former years, principally of metamorphic and intrusive rocks. The approaching publication of several sheets and descriptive memoirs from this region has rendered necessary the revision of the petrographical collections which have been made during the progress of the field work, and has suggested problems for special investigation. This seems, in consequence, to be a favourable opportunity to discuss some of the outstanding results of the study of the rocks of the Southern Highlands of Scotland. Dr. J. S. Flett.

The groundwork of this area is formed of masses of sedimentary rock, the age of which is at present uncertain, and these differ to an extraordinary degree in their state of metamorphism in the various sub-districts included in this extensive country. Omitting for the present all consideration of the rocks which form the narrow strip which is supposed to be of Arenig age, and which lies on the southern margin of the Highlands, and is apparently bounded by faults on both sides along most of its extent, we find among the Highland rocks some in which the metamorphism is no more advanced than in the greywackes or shales of the Southern Uplands. So little have they been affected by the earth movements and other agencies which induce metamorphism that they can hardly be distinguished from the Arenig (?) rocks of adjacent areas. In the finer shales the original bedding is so little obscured in some cases by the development of slaty cleavage that the geologist is at once impressed by the possibility that a

* "The Geology of parts of North Lincolnshire and South Yorkshire." *Mem. Geol. Survey* (1890), p. 7.

Digitized by Google

Dr. J. S. Flett. careful search might reveal the presence of fossils. The grits are quite as little modified; the original clastic structures are perfect; the original clastic micas are visible in abundance; while cataclastic structures and new micas are surprisingly little in evidence. A re-examination of the Highland series in the vicinity of Aberfoyle has confirmed the opinion already formed by the field officers that the metamorphism in that quarter is of the most rudimentary kind.

Mr. J. B. Hill in his paper on the progressive metamorphism in the neighbourhood of Loch Awe* has described very similar rocks from that region, and in Banffshire, many miles to the north-east of this, Mr. Hinxman has observed on the headwaters of the Deveron (Sheet 85) grits and shales, which, though often indurated by the contact action of adjacent intrusive masses, have still their clastic characters very perfectly preserved.

Such areas of low metamorphism, however, are not usually extensive, the largest being probably that which stretches along the southern border of the Highlands from Cowal through Aberfoyle and Callander into Perthshire, where the rocks gradually assume that highly crystalline character which Mr. Barrow has described† in the regions drained by the rivers North Esk and South Esk, in Forfarshire. Throughout this tract the degree of metamorphism is low as a rule, though not everywhere the same. But as we pass northwards the metamorphism increases with great rapidity. There are cases in which, in little less than a mile as measured across the strike, coarse felspathic grits can be seen to pass through various intermediate conditions into granulitic quartzose gneisses in which clastic structures have been entirely obliterated. Most interesting to the student of metamorphism are sections such as may be observed near the Trossachs Pier on Loch Katrine, or on the west shore of Loch Lomond, near Inverbeg, where, in a single exposure, all stages in the passage of a grit into a foliated gneissose rock can be exemplified. In the forthcoming explanations of Sheets 38 and 55 the materials obtained from a study of such sections, and the conclusions they lead to, will be discussed in reference to the geology and structure of the districts in which they occur.

The great sedimentary series of the Southern Highlands—conglomerates, grits, greywackes, shales, limestones, and the problemetical "Green Beds,"—is penetrated by igneous intrusions, which, as regards their age and geological relations, fall naturally into two subdivisions. Of these one is the older and has preceded part, at least, of the movements to which the area has been subjected. They are, in consequence, foliated, though it is

* J. B. Hill. "On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe," *Quart. Journ. Geol. Soc.*, vol. lv., p. 470, 1899.

† George Barrow. "On Silurian (?) Rocks in Forfarshire and Kincardineshire along the Highland Border," *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328, 1901. "On an Intrusion of Muscovite-biotite Gneiss in the S.E. Highlands of Scotland, and its Accompanying Metamorphism," *Quart. Journ. Geol. Soc.*, vol. xlix., p. 330.

Digitized by Google

important to remember that, like the sediments they pierce, they vary much in degree of their metamorphism. Some are, in fact, gabbros, norites, peridotites, or granites, with their original minerals well preserved, and exhibit the characteristic structures of plutonic igneous masses. On the Deveron, in Banffshire, in the district already mentioned, where the sediments show so little alteration (Sheet 85), there are gabbros and serpentines which are indeed affected by the earth movements which resulted in the foliation of the area, but are still so little modified that their igneous structures are very well seen. As metamorphism advances they pass through flaser gabbros into epidiorites and hornblende-schists, and this last is the prevalent type of basic intrusive rock throughout the Southern Highlands. Dr. J. S. Flett.

The porphyritic andesitic basalts of the Loch Awe series as described by Mr. J. B. Hill are further examples of the perfect preservation of igneous structures in the rocks of this group.

It is not only in the degree of their metamorphism that great variations can be traced. In chemical composition they exhibit differences which are quite as great. As already stated, they are mostly rocks of basic affinities, epidiorites and hornblende-schists. With these occur peridotites and serpentines, with various kinds of talcose, actinolite-schists, which have developed from the shearing of ultra-basic masses. But acid gneisses, which correspond to biotite- and biotite-hornblende-granites are also known, as has been shown by Mr. Kynaston in the district around Dalmally, Argyllshire, and the passage from the hornblende-schists to the older granites and gneisses can now be bridged over almost completely.

Another feature worthy of mention is the presence of fine-grained and vesicular igneous rocks in association with others of the coarse-grained type which predominates.* In Sheet 85, on the Deveron, in Banffshire, Mr. Hinxman has mapped fine-grained vesicular hornblende-schists, the vesicles being filled with calcite. When the rock weathers it has quite a pumiceous aspect. It seems quite possible that these may be contemporaneous lava flows, but the very similar rocks from Loch Awe, Mr. J. B. Hill regards as intrusive. There can be no question that, as a whole, the hornblende-schists are intrusive sheets. This can often be proved by their transgressive junctions and their fine-grained chilled edges. Where the original structures can be traced they are those of slowly cooled masses. Occasionally they induce contact alteration in the sediments they break through. This, in most cases, amounts only to a slight induration, but on the Blackwater, in Sheet 85, a slate can be shown to pass at its contact with an intrusive mass of gabbro, epidiorite and serpentine, into a silvery mica-schist with large crystals of staurolite and andalusite. Such evidence of thermal alteration, however, is exceptional.

The rocks which are being mapped by the Geological Survey as "Green Beds" include a very great variety of petrographical

* *See* Mr. Kynaston's remarks, *Summary of Progress of the Geological Survey of the United Kingdom* for 1890, p. 33.

Digitized by Google

Dr. J. S. Flett. types. They are a group of sedimentary rocks characterised by the abundance of chlorite, epidote, or hornblende, and this gives them a green colour and a peculiar method of weathering. In the south-western part of the Southern Highlands, in Cowal, and on Loch Lomond, they are mostly chloritic and epidotic grits, and rarely contain hornblende. But the "Green Beds" of Central Perthshire, and of Forfarshire, are rich in hornblende and constitute a remarkable series of hornblende-schists of sedimentary origin. Mr. Cunningham Craig has paid special attention to the "Green Beds,"* and in the valley of the Tay, near Aberfeldy (Sheet 55), he has found that it is often a matter of some difficulty to distinguish between the intrusive hornblende-schists and those belonging to the "Green Bed" series. As a rule indications are not wanting which enable the field-geologist to discriminate between them. The "Green Beds" may be seen to pass gradually into sheared grits by increase in the proportion of quartzose detritus; the intrusive hornblende-schists show fine-grained chilled edges and the coarser central parts of the sheets have a quite distinctive appearance. But it is astonishing how closely the rocks of one group may resemble those of the other. Some "Green Beds" are fine-grained, well foliated hornblende-schists, with a little quartz and felspar, and not uncommonly biotite and garnet. There is very little to distinguish them from the finer epidiorites, but a careful search of the outcrops will usually show the presence of pebbly bands containing large, well-rounded grains of quartz, obviously clastic in origin. Where the metamorphism is greater the pebbles are drawn out into granulitic quartzose augen, and appear gradually to blend with the schist and become lost in the foliated matrix of the rock.

Of the older granites little that is new has this year been ascertained. They are well known to include types ranging from extremely acid muscovite-gneisses and pegmatites to biotite-gneisses such as that of Ben Vuroch, and are believed to have effected great contact metamorphism in certain districts.

During the year 1901 the principal area of the newer granites in Scotland to be submitted to microscopic examination was that of Ben Rinnes, in Elginshire, which proved to contain the usual association of biotite-granite, diorite and augite-diorite, with subsidiary masses and veins of muscovite-granite, aplite and muscovite-pegmatite. On the east side of Loch Lomond a mass of hypersthene-diorite, or hyperite, already known, has been further examined, and shows some interesting contact phenomena. At Netherly, near Rothes, Elginshire, a mass of diorite, one of the facies of the newer granite of Ben Rinnes, has converted the micaceous schists of the Moine series into cordierite-hornfelses, with andalusite, sillimanite, and garnet.

The dyke rocks of the Southern Highlands, associated with the newer granites, have received much attention and study, both in the field and with the microscope. Their great abun-

*Summary of Progress of the Geological Survey of the United Kingdom for 1900, p. 25.

Digitized by Google

dance and diversity makes them a peculiarly fascinating subject. Dr.J.S.Flett.
Their relations to the newer granites are always sufficiently close to establish a community of origin, though there are cases in which they cut the granites, and others in which they are altered and hornfelsed by adjacent granitic intrusions. Two distinct series of dykes can be established—the porphyries (and porphyrites) and the lamprophyres. Space will not permit of a discussion of the classification of the dyke rocks as a whole, but a few remarks may be made on the most difficult group, the lamprophyres.

Owing partly to their inherent variety, partly to the great readiness with which they decompose, and partly to their propensity to develop distinct facies in different parts of their course, it is no easy matter to say exactly to what subdivision of the group any particular example is to be assigned. Their essential minerals, biotite, brown hornblende, orthoclase, and plagioclase are often all present in the same specimen, and may occur in any relative proportion. The classification at present in use is simple, and appears to be the most satisfactory that can be proposed, though admittedly there are individual occurrences which lie on the border line between the various groups. The dykes consisting principally of biotite and orthoclase are minettes; of biotite and plagioclase, kersantites; while those in which hornblende preponderates fall into the vogesites (orthoclase and hornblende), and the spessartites (plagioclase and hornblende). For rocks containing both biotite and hornblende there is a choice of terms: mica-vogesite or hornblende-minette, and mica-spessartite or hornblende-kersantite, the use of which will depend on whether hornblende or biotite is the dominant ferro-magnesian mineral. Thus, if the section contains orthoclase with hornblende and a subordinate amount of biotite, the last named may be regarded as an accessory mineral, and the designation employed would be mica-vogesite or mica-bearing vogesite.

The grouping adopted is, however, entirely artificial, and it should not be forgotten that a vogesite dyke may pass into minette or spessartite as it is traced along its course. A further difficulty arises from the rapid decomposition which characterises the lamprophyre group. They are often so charged with secondary carbonates that the determination of their felspar is impossible. For these and other reasons it is advisable to retain the generic designation "lamprophyre" to mark the outcrops as shown on the maps.

A word may be added regarding the term spessartite and the relations of the spessartites to the camptonites. As Rosenbusch has pointed out there are two series of lamprophyres, consisting essentially of plagioclase felspar and hornblende, which differ so greatly from one another in physical characters, chemical composition and geological affinities, that they cannot be united. The spessartites belong to the granitic-dioritic magmas, and are associated with vogesites, minettes, and kersantites. The camptonites are associated with alnöites, monchiquites, and

Digitized by Google

Dr. J. S. Flett. fourchites, and seem to have been mostly emitted from foyaite, essexite, and theralite magmas. The spessartites are rather of intermediate, the camptonites of highly basic character. The deep red-brown hornblende of the camptonites differs considerably from the paler, often greenish-brown hornblende of the spessartites, and while quartz is frequent in the latter, it is absent from the former. The augite of the camptonites is dark purplish-brown, of the spessartites mostly pale clear green. At present it cannot be said with certainty that typical camptonites do not occur in the Southern Highlands, as certainly some very basic hornblende bearing lamprophyres are known there, but if they do occur they are rare.

It will be noticed that according to the nomenclature here adopted the "camptonites" will be subdivided into the spessartites and camptonites, and the former are far the most common throughout Scotland.

In the report of this department for the year 1900, Mr. Teall has recorded the very important observation that in Assynt (Sutherlandshire), the dark coloured hornblendic lamprophyres are accompanied by a light coloured felspathic series which he calls "felsites." We have in fact a development of complementary rock suites, a melanocratic and a leucocratic group forming a diaschist-complex as defined by Brögger. It has long been known that in the Southern Highlands there are pale felspathic dykes which have been variously named felsites, orthofelsites, trachytes, etc. Their close relation to the lamprophyres has been noted by more than one of the field officers. They consist almost entirely of orthoclase, are often fine grained and frequently porphyritic. One point is of some importance as regards their origin. and that is that they often show the large corroded xenocrysts of quartz so common in lamprophyric rocks, while quartz is usually absent from the groundmass. It is in every way probable that we have here a leucocratic complementary series to the melanocratic lamprophyres, such as has already been shown to exist in Sutherlandshire.

A further interest has been lent to the study of the dyke rocks of the Scottish Highlands, during the past year, by Mr. Grant Wilson's discovery in Glen Finnan, Inverness-shire, of an occurrence of typical malchites (Rosenbusch). Though they lie outside the area with which we have been dealing in this Report, they are of sufficient interest to merit a brief description.

The malchite dyke rocks from Glen Finnan are grey and fine-grained, consisting of hornblende and plagioclase, never conspicuously porphyritic in the hand specimen, and bear a general resemblance to fine-grained diorites, though on the whole paler in colour than the majority of dioritic rocks. Many of them exhibit a parallel structure which in most cases is the result of fluxion; others are entirely massive.

Although consisting essentially of hornblende and plagioclase they contain as a rule more or less biotite, and this may so increase in quantity as to almost entirely replace the hornblende. A certain amount of orthoclase may be present, and

Digitized by Google

occasionally a very little quartz. The accessory minerals include sphene, apatite, magnetite and zircon, while epidote, chlorite, rutile, calcite and muscovite are secondary. One specimen contains orthite. Dr. J. S. Flett.

The hornblende is in small prisms often perfectly idiomorphic in transverse section, but usually elongated and irregularly terminated. Its colour is pale green to dark green, or dark bluish-green, and a very characteristic feature is the presence of minute dark enclosures, which have a regular orientation within the crystal. Often the crystals have a clear centre surrounded by one or two zones dark and turbid with these enclosures, while the external margins may be transparent and free from them.

The biotite is sometimes fox-brown, at other times greenish. It forms small irregular scales devoid of crystalline form. Biotite and hornblende are often aggregated together to form elongated clusters which may be conspicuous in the hand specimen, giving it a streaky appearance, suggesting foliation.

The felspar is mostly plagioclase, but in some of the slides there seems to be a certain amount of orthoclase. The prevailing felspar is perhaps andesine. Quartz in most cases is practically absent.

The structure is commonly panidiomorphic, all the minerals showing some idiomorphism, and this is especially true of the hornblende and the felspar. Some of the slides are really porphyritic, hornblende and plagioclase appearing in small idiomorphic phenocrysts in a groundmass of irregular smaller felspars. The phenocrysts are never large, and the porphyritic character is not obvious in the hand specimens.

Several of these dykes correspond exactly with certain types of malchite as described by Osann,* Chelius,† and Rosenbusch.‡ Others show not unimportant divergence from the original types. A description of these may be conveniently reserved till the mapping of their area of distribution is more advanced, and more is known about their varieties and mode of occurrence.

III. CHEMICAL WORK.

During the first half-year analyses of rocks and minerals for officers in the field and for the Petrographical Department were made. In June Mr. E. G. Radley was appointed as general assistant in the laboratory. During July and August various analyses were made amongst which might be mentioned a rottenstone and the unaltered limestone from which it is derived, for Mr. Cantrill; a coal from the Colonial Office, and a coal seam which passes laterally into dolomite, for Dr. W. Pollard.

* Osann, A. *Ueber dioritische Ganggesteine im Odenwald.* Mitth. d. Grossh. Bad. Geol. Landesanst, 1892. II. p. 380.

† Chelius, C. "Das Granitmassiv des Melibocus und seine Ganggesteine." *Notizbl. Ver. f. Erkunde,* Darmstadt. 1892.

‡ Rosenbusch, H. *Mikroskopische Physiographie,* B. II., p. 448. 1896

Digitized by Google

Dr. W. Pollard.

Mr. Strahan. In August, at Mr. Strahan's request, the chemist was sent to Swansea to confer with and receive instruction from Mr. C. A. Seyler, B.Sc., F.I.C., etc. (Public Analyst for the counties of Carmarthen, Glamorgan, Pembroke, and the Borough of Swansea, and District Agricultural Analyst for the county of Glamorgan), in connection with the analyses of coals from the South Wales Coalfield.

In October the analyses of these coals was commenced, and the first ten samples completed by the end of the year.

Owing to the increased demand on the part of the officers in the field and the Petrographical Department for chemical investigation, it has been found necessary to provide for a second time temporary accommodation sufficient for another worker. For this purpose the gallery leading to the chemical laboratory is to be fitted with a working bench, etc., where Dr. Flett hopes to be able to perform certain investigations in connection with petrological work, as the chemist and assistant are fully employed on problems envolved by the mapping of the South Wales Coalfield.

In the following report the most interesting portions of the year's work in the laboratory will be found, together with a short account of the methods of analysis in use in connection with the coal investigation.

The sincere thanks of the Geological Survey are due to Mr. Seyler, for his kindness in assisting and advising on this investigation.

ANALYTICAL METHODS IN USE IN CONNECTION WITH THE EXAMINATION OF SOUTH WALES COALS.

The methods in use in connection with this investigation are given rather fully, as it is well known in coal analysis that slight variations in methods (especially in the determination of volatile matter) may produce considerable variations.

Most of these methods are practically the same as those recommended by the Commission on Coal Analysis of the American Chemical Society (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1116).

Sampling.—The samples as received at the laboratory are packed in large biscuit tins which are enclosed in wooden boxes. The weight of the sample is about 20 to 30 lbs. and usually contains no pieces larger than a small orange. All pieces larger than a walnut are crushed in a small Marsden-Blake crusher. The sample is then thoroughly united and quartered in the usual way to about 5 to 10 lbs. This portion is again passed through the crusher, united and quartered to about ¾lb. This is at once transferred to a stoppered bottle and subsequently ground in a coffee mill set fine. The powder is at once transferred to two stoppered bottles, one for analysis, the other being at once tied down and sealed in case it should be required for future reference. The rest of the coal is at once replaced in its tin and also tied down and sealed.

Digitized by Google

Dr. W. Pollard.

It should be mentioned that a small quantity (about 150 grammes) of the last quarterings not required for sample are passed through the mill immediately before the sample for analysis is ground, to remove any dust or remains of a former coal left in the mill. The amount of coal left in the mill which might be thought to influence the next sample ground is so small as to render it unnecessary to take the mill to pieces after each time of using. The mill has been taken to pieces several times and on no occasion has more than a gramme of coal been found in it. As at least 300 grammes of each sample go through the mill (not to mention the first 150 grammes alluded to above for cleaning purposes), it will be seen that no appreciable error could arise on this account.

The sample in the condition in which it comes from the mill is used for moisture and volatile matter determinations. This will be alluded to as "coarse moist" coal. For other determinations some of this is ground in a mortar to pass the 50-hole sieve. Moisture is determined on this sample also, so that all results can be calculated to the "coarse moist coal."

Volatile matter is determined on the fine as well as the coarse. In most cases the same value is obtained. Should any appreciable difference be found, both are given.

It is a well-known fact that coal loses moisture when ground fine in a mortar. Many samples of this are given by the Commission on Coal Analysis of the American Chemical Society (*loc. cit.*). Some data obtained in this laboratory in connection with this are given under "Moisture" p. 74.

The sample for specific gravity determination is taken from the last quarterings not required for the analysis sample, and that portion only is used which passes the 8-hole and is retained on the 16-hole sieve. In some cases this sample contains considerably more moisture than the others, partly due no doubt to its not being so long exposed to the air before being bottled.

Moisture.—(Determined both on coarse, fine and specific gravity samples.)

One gramme of coal is heated in a Victor Myer bath (toluene being used) for one hour exactly. The temperature obtained is about 105°.

The coal is weighed off between clipped watch glasses, heated uncovered, covered immediately on removal from the bath and allowed to cool in a desiccator.* It is weighed about half-an-hour after its removal from the bath.

The coarse moist sample is also dried in vacuo with sulphuric acid pumice in a Hempel desiccator for twenty-four hours. More moisture is often obtained by this method. (Cf. *Journ. Am. Chem. Soc., loc. cit.*)

The data obtained by drying at 105°. for one hour are, however, always used in calculating the analyses, as this is believed to be the method of determination most frequently employed.

* Sulphuric acid pumice is used in all desiccators in this investigation.

Digitized by Google

Dr. W. Pollard.

Duplicates (by the same method) should agree within ·1 per cent.

The following table gives moistures determined on different samples at 105°, and on the "coarse moist" coal in vacuo with sulphuric acid:—

	One Hour at 105°.			24 Hours Vacuo with Sulphuric Acid in Hempel Desiccator.
Sample No.	Sp. Gr. Sample.	Coarse Moist.	Fine 50 Hole.	Coarse Moist.
1	1·41	1·50	1·22	1·59
2	2·47	1·97	1·90	2·22
3	2·04	1·93	1·66	2·00
4	2·72	2·17	1·97	2·47
5	2·70	2·76	2·39	2·82
6	·80	·87	·86	·82
7	1·55	1·58	1·10	1·61
8	1·10	1·12	1·14	1·10
9	2·48	2·12	1·73	2·16
10	1·79	2·13	1·79	2·08

The above figures represent the mean of two or more determinations.

Volatile Matter.—One gramme of coal is heated in a platinum crucible with well fitting cover, supported on a platinum triangle over a bunsen giving a flame of 20cm. high for seven minutes exactly.

Bottom of crucible 8cm. above mouth of burner. Gas pressure 50mm. of water.

The dimensions of the crucible employed are—Height, 40mm.; diameter at base, 24mm.; at top, 34mm., capsule cover.

A cylinder of clay or asbestos board of about 12cm. diameter should be used to prevent draughts from influencing the flame.

Loss of weight—Moisture = volatile matter.

Duplicates should agree within

·15% on coals containing up to 15% of volatile matter.
·30% „ „ „ over 15% „ „ „

It should be borne in mind that to some extent at least the value found for volatile matter depends on the size of crucible, tightness of cover, strength of flame, etc. It is therefore important in making this determination to keep as closely as possible to definite conditions in order that the figures found for various coals should be comparable.

The method of Meade and Attix (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1137) of heating a second time under identical conditions, and subtracting the second loss from the first is being tried, but as yet sufficient data are not available for comment.

Ash.—As the main importance of knowing the exact amount of ash in a coal is to get the amount of oxygen as near as possible, it has been considered best to estimate the ash left in the platinum boat from the carbon and hydrogen determination.

Digitized by Google

In some cases this agrees perfectly with the value obtained by ashing in a muffle, whilst in others the results vary considerably. Dr. W. Pollard.

This appears to be due to the fact that in the muffle there is less oxidation than in the combustion tube, as might be expected. This seems to be borne out by the fact that the "sulphur in ash" obtained from ash from muffle has (in every case where estimated) been found appreciably lower than the "sulphur in ash" from the boat.

It may also possibly be due to a slight extent to alkalis being partly driven off in the muffle, where the temperature is probably higher than in the boat.* This has, however, not as yet been investigated, but should opportunity subsequently occur, it will be looked into. This variation of ash obtained in the muffle and in the boat has frequently been observed and mentioned by chemists.

Duplicates (by the same method) should agree to within ·1% up to about 4% of ash, and to within ·2% above 4% of ash.

Fixed Carbonaceous Residue.—Obtained by subtracting ash, olatile matter and moisture from 100.

Total Sulphur.—The method of M.W. and J. Atkinson has been adopted with very slight alteration.

The following description of the method is taken from the report of the Commission on Coal Analysis of the American Chemical Society, 1899, vol. xxi., p. 1116. [See also *Journ. Soc. Chem. Ind.*, Mch. 29, 1886. *Journ. Iron and Steel Inst.*, No. 2, 1896.]

"One gramme of finely ground coke or coal is mixed thoroughly "with five grammes of dry sodium carbonate spread evenly over the "bottom of a flat or shallow platinum dish, and the latter placed "on a rectangular rest made of clay pipe stems inside a muffle, "which though hot is still black. The temperature of the muffle "should be raised gradually during half an hour to clear cherry "redness, and then kept at the latter temperature for 10 or 15 "minutes. The sodium carbonate should not sinter or fuse. The "mass should not be stirred. When the carbon is burned, "usually in about 45 minutes in all, cool, digest with 100 to 200cc. "of warm water, allow to settle, decant through a filter, and wash "twice by decantation, and then on the filter adding a few drops "of a solution of sodium chloride if the residue tends to pass "through the filter. The filtrate is acidified with 12cc. concentrated "hydrochloric acid, and precipitated with barium chloride."

To avoid any possibility of all the sulphur not being oxidised to sulphate before acidifying, it has been thought advisable to add a little bromine water (about 15cc.) before the addition of the hydrochloric acid. It has also been found necessary to heat in the muffle longer than 45 minutes to burn off all the carbon.

* It is well known that in the determination of ash in plants, potash is not infrequently lost by volatilisation, unless great care is used in the ashing and the temperature kept sufficiently low.

Digitized by Google

Dr. W. Pollard.

With these slight deviations the method has been strictly adhered to with most satisfactory results.

The muffle used is a Fletcher, No. 461 (heated by gas). Blind experiments with sodium carbonate have frequently been made, both simultaneously with and separately from sulphur determinations, and in no case has sulphur been found to be absorbed from the gas. It is always necessary to test the reagents used for sulphur, and if found, to apply the correction, as it frequently happens that small quantities of sulphur (which in some cases might be sufficient to give ·1% in the coal) are to be found even in sodium carbonate "Puriss."

Duplicates should agree within ·1%.

Sulphur in ash.—This is obtained from the ash from the platinum boat after combustion. The ash is evaporated with hydrochloric acid to dryness, taken up with hydrochloric acid and hot water, solution filtered, and the sulphate precipitated with barium chloride in the usual way. The amount of sulphur obtained here substracted from the "total sulphur," gives "combustible sulphur."

Nitrogen.—Kjeldahl's method has so far been exclusively used, although it is proposed to do a certain number by combustion with soda lime for the sake of comparison. 1 gramme of coal is heated with 20cc. concentrated sulphuric acid, 8 grammes dry potassium sulphate, and a bead of mercury till colourless. Allow to cool, and pour into a flask of about 1000cc. capacity, containing about 200cc. water, rinse out, etc., and when cold add 80cc. of a 50% solution of sodium hydrate, and 20cc. of a 4% solution of potassium sulphide. Distil (using a good splash head) collecting distillate in 20cc. $\frac{n}{10}$ acid. Titrate back $\frac{n}{10}$ or $\frac{n}{50}$ alkali. Indicator Methyl orange.

The mercury (and hence potassium sulphide) may be omitted [Lunge, *Chem. Techn. Untersuchungsmethoden*, 4th edn., Vol. I., p. 228]; in fact, in the determinations made so far one nitrogen estimation has been made with, and one without, the mercury, the only difference observed being that the one with the mercury becomes colourless sooner than that with potassium sulphate only.

Blind experiments should be made, and if necessary a correction applied.

Duplicates to agree to within ·1%.

Carbon and Hydrogen, Ash.—Jena glass combustion tubes about 110cm. long and 12 to 15mm. internal diameter are used.

They are filled as follows:—

Copper oxide roll 6 to 8cm.
Space for boat 16 to 20cm.
Copper oxide from wire, not too coarse, about 50cm.
Lead chromate pumice 8cm.
Silver spiral 7cm.

The furnace used is a Fletcher combustion furnace, No. 2 pattern, 36 inches long. The boat is of platinum, 10cm. long. The purifying train (one for air and one for oxygen, with a three-

Digitized by Google

way tap, so that the gas can be changed at once) consists of an Emmerling's absorption tube, filled with pumice about the size of peas, which is freshly drenched with 1 in 2 potash before each combustion 35 to 40cm. long, 20mm. internal diameter. Two wash-bottles, the first with potash the second sulphuric acid, followed by two large U-tubes with pumice saturated with concentrated sulphuric acid. (The pumice should be drenched with sulphuric and ignited in a muffle to expel chlorides, etc.) Between the three-way tap and the combustion tube a small sulphuric acid wash-bottle is placed (so that the rapidity of the gas current can be easily watched), followed by a small mercury trap. Dr. W. Pollard.

For the collection of water a U-tube, filled with sulphuric acid pumice, is used. Before each combustion this tube is filled with concentrated sulphuric overnight, and the acid drained off immediately before weighing.

Geissler bulbs are used for absorbing the CO_2 with a drying tube 8cm. long, filled with freshly-crushed potash. A small U-tube, with sulphuric acid pumice, is used after the bulbs, to absorb any moisture that might be carried over. This tube, however, seldom gains more than a milligramme. Finally a protecting tube of sulphuric acid pumice. It is scarcely necessary to say that the bulbs and solid potash tube are refilled before each combustion.

Although it is unnecessary to go into details about the combustion, the following points may be worth mentioning.

The boat should contain as nearly as possible ·5 gramme of coal (when dried). This has been found the most convenient amount to work with for accuracy. The fine-powdered coal (50-hole sample) should be used. The boat and coal should be dried at 105° for one hour exactly, cooled, and weighed in a stoppered tube immediately before required.

When the boat is placed in the combustion tube, it is best to rest it on a strip of platinum foil, to prevent it from adhering to the tube or from picking up any fragments of copper oxide.

Before commencing to heat the boat, the copper oxide must be at a bright red heat, the silver spiral and copper roll at a fair red heat, the lead chromate at a dull red heat. When these have been got to the required temperature, the boat is gradually heated (commencing at the copper roll end) in a gentle air current, until the volatile matter is practically all off; the oxygen is then turned on, and the combustion completed in the usual manner.

Duplicates should agree within

Hydrogen	·1%
Carbon	·2%

It is of the greatest importance that the copper oxide be hot enough before the boat is heated at all, as presumably methane would be amongst the first of the volatile products to come off; and it is well known that this gas requires a high temperature for complete combustion.

Digitized by Google

Dr. W. Pollard.

In two combustions made recently, there seemed some reason to suspect that methane had escaped combustion, as the difference between the carbon and hydrogen of the lower to the higher result gave the ratios of

$$C : H = 1 : 3{\cdot}5 \text{ and } 1 : 3{\cdot}8$$

whilst the ash in each case agreed.

On repeating these, concordant results with the higher value were obtained. Another source of error, when duplicates agree in the hydrogen but not in the carbon, may be due to all the carbon not being combusted, a little remaining with the ash. This has been found to occur on more than one occasion, in each case the coal having a high caking power and considerable ash (over 5%). It was owing to this that a boat 10cm. long is now used instead of one of the usual size, as the half-gramme of coal can be spread out into a very thin layer, thus reducing the chance of incomplete combustion. The following is an example of the error just described.

A boat 5cm. was used, and the caking power of the coal was about 45.

	I.	II.	III.
C	79·72	79·97	80·13
H	4·75	4·76	4·82
Ash	8·38	8·12	7·98

It will be seen that the hydrogens all agree to within ·1%, whilst the carbons are varying considerably. Nos. 2 and 3 are within the limit allowed of ·2%, but No. 1 is too low. On comparing the ashes, it is seen that the difference of Nos. 1 and 2 to 3 are ·40 and ·14 higher respectively, whilst the carbons of 1 and 2 are respectively

·41 and ·16.

Assuming the ash of No. 3 to be nearer the correct amount—the ash was nearly white, whilst 1 and 2 were grey—and subtract the ash of No. 3 from Nos. 1 and 2, adding the difference to the carbon, we get for the carbon

80·12 80·11 80·13.

It has been suggested that one cause of low carbon results might be due to some carbon monoxide escaping combustion to dioxide. At Mr. Seyler's suggestion, a small flask, containing a dilute solution of sodium palladium chloride, was placed behind the protecting **U**-tube, so that all gases escaping from the combustion and not previously absorbed by the **U**-tube and potash bulbs, must pass through this solution, and render it possible to detect monoxide. On no occasion has the solution been darkened, in spite of one or two low carbon determinations, which could only be explained—as the hydrogens and ashes agreed—by assuming a leak had occurred, although none had been detected, or from some other cause unknown.

One or two other possible causes of error in coal combustion may be briefly alluded to. The carbon percentage may be affected to a marked extent by the way in which moisture is determined. If the moisture value obtained by drying in vacuo

Digitized by Google

over sulphuric acid more nearly represents the true moisture than the value obtained by drying at 105° for one hour, in certain cases the carbon may easily be a few tenths of a per cent. out. All coals analysed in this laboratory have moisture determinations done by both methods, but the value obtained by drying at 105° for one hour is exclusively used in calculating results, as this is the method more usually employed. The carbon, hydrogen, and ash are calculated first on the dry coal, and subsequently from these figures on to the "moist coarse" coal and dry ash and sulphur-free coal. The following example illustrates an error of the kind described:— Dr. W. Pollard.

Moisture at 105° one hour	2·17%
„ vacuo sulphuric acid	2·47%
Carbon on dry coal	82·80%
Calculated on to the "coarse moist" coal	
by moisture at 105°	81·00% Carbon
by moisture in vacuo	80·76% „

giving a difference of ·24% on the carbon, which is outside the limit within which duplicates should agree.

This may be an exceptional case, as such a large difference as ·3% in the moisture determined by the two methods is not often found. Where, however, coals rich in moisture have to be dealt with, it may be of importance to use both methods of moisture determination.

Two more sources of error will be just mentioned: first, the presence of carbonates in the coal, and, secondly, the error due to pyrites. A discussion on the latter will be found in the Report of the Coal Analysis Commission of the American Chemical Society *(loc. cit.)*.

In calculating the composition of coals in this laboratory no correction has been applied for either of these errors, as, in connection with the pyrites, it is impossible to say whether the sulphur may not, at any rate, partly be in combination in the coal.

Caking Power.—The platinum crucible used for this determination has the following dimensions:—

Diameter at top 42mm., at base 30mm.
Height 50mm. Capsule cover.

The coal is powdered to pass the 50-hole sieve; sand to pass the 40-hole and stay on the 50-hole sieve. The coal and sand are mixed in varying proportions, but so that the total weight of the two used for an experiment always is the same; 25 grammes being the weight used.

The charge having been placed in the crucible, it is heated exactly as for "volatile matter" determinations, allowed to cool, and when cold the cake is removed, placed on a flat surface, and a 500-gramme weight cautiously placed on the cake. When the cake *just* crushes the caking power is reached.

The caking power is expressed as the weight of sand required per weight of coal.

			Sand.	Coal.
Thus:	Caking Power =	4	20·0	5·0
		9	22·5	2·5
		24	24·0	1·0

Digitized by Google

Dr. W. Pollard.

The test is a rough one, and not capable of great accuracy.

Specific Gravity.—Estimated on about 5 grammes of the sample specially set aside for this determination, in a specific gravity bottle. Air is removed by an air pump.

Moisture and ash determinations as made on this sample was to be able to correct to dry and dry ash-free coal.

The correction for ash is made by deducting ·01 from the specific gravity for each 1% of ash found.

The ash on this sample is determined in the muffle.

The results obtained are tabulated thus :—

PROXIMATE ANALYSIS.

Moisture Volatile matter. Fixed carbonaceous residue Ash	}	Given on (1) moist coal ; (2) dry ash-free coal.
Total - -		100·00

ULTIMATE ANALYSIS.

Carbon Hydrogen Oxygen Nitrogen Combustible sulphur Ash Moisture	}	Given on (1) moist coal ; (2) dry coal ; and (3) dry, sulphur and ash-free coal.
Total - -		100·00

Sulphur in ash
Total sulphur
Caking power
Specific gravity

ROTTENSTONE FROM SOUTH WALES.

The following analyses were made for Mr. Cantrill, to ascertain, if possible, what occurred in the conversion of the black limestone to Rottenstone.

For this purpose bulk analyses of the three samples were made, together with analyses of the residue obtained by treatment with dilute hydrochloric acid and boiling for about three minutes.

Samples of the residue from 1 were examined under the microscope, and found to contain minute cubes and apparently spheres of pyrites, the spheres may only be coated with pyrites.

A sample of the coarser constituents of 3 obtained by washing, by decantation with water, showed no cubes. Spheres were there, but of an iron-red colour, presumably due to ferric oxide from the oxidation of the pyrites. After this residue had been boiled with dilute acids, the spheres were no longer visible, the red colour had disappeared, and all that remained seemed to consist of a micaceous mineral and some cryptocrystalline silica.

Digitized by Google

Dr. Flett has given the following description of the black limestone (sample 1):— Dr. W. Pollard.

E 3401. BLACK LIMESTONE S.W. OF CWM HAFFES, GLYN TAWE, TAWE VALLEY.

"A fine-grained dark limestone without organic structures, and consisting of small irregular grains of calcite, the surface of which are coated with brown films of limonite or organic matter or both. A few very small cubes of pyrites and flakes of colourless mica are the only visible impurities. There is no detrital quartz, and the silica shown in the analysis must exist as a thin framework of chalcedonic character between the calcite grains."

The following are the results obtained by analysis:—

1. Limestone which, on weathering, yields Rottenstone.
2. Inferior quality Rottenstone.
3. Best quality Rottenstone.

	1.	2.	3.
SiO_2 - - -	16·50	70·87	80·82†
TiO_2 - - -	·07	·55	·29
Al_2O_3 - - -	1·25	9·78	5·82
Fe_2O_3* ‡ - -	·50	4·61	3·79
CaO - - -	44·00	1·60	1·43
MgO - - -	·69	1·32	·88
CO_2 - - -	34·86	·27	Not found
P_2O_5 - - -	·36	1·39	1·36
FeS_2‖ - -	·32	Not found	Not found
Na_2O - - -	Trace	·56	·30
K_2O* - -	·32	2·43	1·40
H_2O 105° - -	·17	2·18	1·27
H_2O above 105° + Organic Matter	1·31	4·62	2·82
TOTAL - -	100·35	100·18	100·18

* Traces of MnO and Li_2O in all three.

† Less than 1% of colloid silica in No. 3.

‡ All Fe calculated as Fe_2O_3.

‖ S in 1 mostly as pyrites but probably a little pyrrhotite. All calculated as pyrites.

Digitized by Google

Dr. W. Pollard.

The percentage of insoluble residue (prepared by boiling in dilute hydrochloric acid, etc., and igniting)

= 18·75 85·18 88·65

and the composition of these residues, expressed in percentage of the residue—

	1	2	3
SiO_2	88·14	83·20	91·17
TiO_2	·39	·64	·33
Al_2O_3	6·75	10·36	6·01
Fe_2O_3*	2·58	1·92	·69
CaO	·12	·23	·65
MgO	·73	·89	·70
K_2O	1.70	Only estimated in bulk not in residue.	
Na_2O	Trace.†		

* All iron calculated as Fe_2O_3. † = less than ·05 %.

The analysis of the second quality Rottenstone (No. 2) is not really comparable with Nos. 1 and 3. The much larger amount of alumina in the residue and the alkalies of the bulk, being so much higher than in No. 3, seem to point clearly to there being more clastic material (micaceous minerals are recognisable in all three samples under the microscope) than in the other specimens. It will, therefore, not be considered further in detail.

On the other hand, Nos. 1 and 3 are distinctly comparable. In the following table No. 1 has been re-calculated after elimination of all lime and carbonic acid, and as much magnesia as is required by the excess of carbonic acid; all moisture and organic matter and the pyrites calculated to Fe_2O_3. It should be remarked, in connection with No. 1, that no high accuracy can be placed on even the first decimal, as after elimination of the above-mentioned constituents (roughly 80%) the amount of original substance taken for analysis would be represented by about ·2 gramme.

In No. 3 lime, moisture and organic matter have been eliminated.

One hundred parts would therefore contain—

	1.	3.	Difference.
SiO_2	84·03	85·47	1·44
TiO_2	·36	·31	·05
Al_2O_3	6·35	6·13	·22
Fe_2O_3	3·61	4·00	·39
MgO	2·19	·93	1·26
P_2O_5	1·83	1.41	·42
Na_2O	Trace.	·32	·32
K_2O	1·63	1·43	·20

From these figures it will be seen that Nos. 3 and 1 are almost identical.

Digitized by Google

What has happened is that the carbonates have been extracted from the Limestone by weathering, leaving behind the siliceous matter which makes "Rottenstone." It is also clear that nothing has been introduced during the process of weathering, nor has anything, except the carbonates and sulphur, been removed. Dr. W. Pollard.

The value of the Rottenstone appears to be due to the high percentage of siliceous material in a fine state of division.

WEATHERING OF MAGNESIAN LIMESTONE.

During the summer of 1899, whilst the Jermyn Street front of this Museum was being renovated, the opportunity was taken of collecting several specimens of the stone, to see how it had been affected by half a century of London atmosphere.* Owing, however, to more important work having to be attended to, it was not possible to complete the examination till recently. An interesting paper has appeared recently by Mr. E. G. Clayton, F.I.C., "On an Incrustation from the Stone Gallery of St. Paul's Cathedral." [*Proc. Chem. Soc.*, vol. xvii., p. 201 (1901).]

This paper is of great interest in connection with Portland stone in London atmosphere.

The report on the selection of stone for the Houses of Parliament [By Charles Barry, H. T. De la Beche, William Smith and Charles H. Smith. London: 1839] should be referred to, as it was a similar stone to the one recommended that was used in this Museum. The stone used here was from North Anston, Yorks, and its composition is given as—

		Upper Bed.	Fourth Bed.	Lower or Eighth Bed.
† 1.	Calcium Carbonate - -	52·0	52·5	52·8
	Magnesium Carbonate -	45·2	44·7	44·4
	Oxide of Iron and earthy matter	2·0	2·1	2·1
	Moisture- - - - - -	·8	·7	·7
		100·0	100·0	100·0

‡ 2.	Calcium Carbonate - - -	54·89	55·37
	Magnesium Carbonate - -	42·07	41·71
	Protoxide of Iron - - -	·49	·73
	Peroxide of Iron - - -	·24	—
	Protoxide of Manganese - -	Trace	1·68
	Silica - - - - - - -	·56	·92
	Water - - - - - - -	·51	·45
		98·76	100·86

* The Museum was erected during 1848 to 1851. Sir James Pennithorne, Architect.

† 1. From "Lithology," by C. H. Smith, read at Royal Inst. Brit. Architects, April 29th and June 3rd, 1844. Analyst, R. Phillips, F.R.S.

‡ 2. G. F. Harris, "British Building Stones," from *The Builder*, Nov. 20th, 1886, p. 754. Analysts, Ransome and Cooper.

Digitized by Google

Dr. W. Pollard.

From these analyses it will be seen that the stone is as near a true Dolomite as possible, the ratio of lime to magnesia (mean of these five analyses) being 1 : ·97.

The following are the main points observed in this examination. The stone facing S.W. was more weathered than that facing S.E., doubtless due to the S.W. winds being mostly wet, and to its being the prevailing wind (cf. Report, p. 4). It is impossible to give any exact figures as to the amount of stone which has been weathered, or has flaked off, but probably it is something between 1 and 3mm. This rough estimate was made possible by the fact that the stone contains occasional segregations of calcite crystals. These have stood the weather much better than the stone itself, and stood out wart fashion on the surface. Where the rain had fallen directly, the stone was rather less black than where it was sheltered. Only a trace of magnesium sulphate could be found on the exposed surfaces, whilst an appreciable amount was found where the stone was sheltered.

A microscopic section of a specimen that had been sheltered from the direct action of the rain was prepared, showing the surface in section, which Dr. Flett has described as follows :—

The following notes on the microscopic characters of specimens of the stone of which the Museum of Practical Geology is built, and of their weathered surfaces, are by Dr. J. S. Flett :—

The stone is a granular yellow dolomite consisting mostly of small rhombohedra, often rounded and slightly irregular in outline, but showing perfect crystalline form when occurring in cavities and veins. It contains many irregular-shaped pores, which are sometimes filled up with re-crystallised dolomite, and through the rock are scattered rounded patches, apparently concretionary. The blackened surface of the under part of the moulding from which the fragment was taken has been preserved, and is well seen in the section. It is covered with small crystals of gypsum, mostly in the form of monoclinic prisms and swallow-tailed twins. These form a layer mixed with black particles, probably sooty matter, and resting on a thin black film, beneath which the rock is unattacked. The average length of these crystals is about $\frac{1}{100}$ inch, and the thickness of the deposit, as preserved in the section, a little greater than this. Outside of the thin basal carbonaceous layer there is no dolomite, but only gypsum, which has, apparently, been formed by the evaporation of aqueous solutions of sulphate of lime, which have leached out of the stone. The black film upon the surface of the dolomite can be seen, where it is less opaque than usual, to consist of fibres of gypsum crossing irregularly and mixed with black particles, apparently carbonaceous.

This formation of calcium sulphate, or gypsum, on the surface of marbles and limestones in town is well known.

Sir A. Geikie has gone very thoroughly into this in connection with "Rock Weathering, Measured by the Decay of Tombstones" (*Geological Sketches at Home and Abroad*, MM. & Co., 1882, p. 182, and *Proc. Royal Soc. of Edinburgh*, 1880).

Digitized by Google

In '*Geological Sketches*' a figure of the altered surface of a marble will be found, which had stood for eighty-seven years in Edinburgh. Dr. W. Pollard.

The black edge of gypsum and soot similar to that described by Dr. Flett in his account of the microscopic characters above, is very clearly shown.

In addition to this gypsum deposit on the stone of this museum, in one or two places sheltered from rain, small crystals, some as long as 3mm., were found. These occurred presumably where condensed moisture had evaporated. They were found to be magnesium sulphate.

What has occurred is that the sulphurous and sulphuric acids in the air have attacked the dolomite forming calcium and magnesium sulphates, and the latter being more soluble has to a great extent been leached out. This is entirely borne out by the following analysis. The sample was collected from the surface of the stone as scraped off by the masons in cleaning it. Hence a certain amount of unaltered stone is also in the sample.

The composition was found to be—

Ignited insoluble residue	5·2
Oxides of Iron and Alumina	1·4
Lime	26·9
Magnesia	9·5
Sulphur Trioxide	20·7
Carbon Dioxide	19·4
Water lost at 105°	1·8
„ „ between 105° and 150°	9·1
Water above 150° + organic matter	6·5
	100·5

If we assume the following molecules to be present (the magnesium sulphate was calculated from the amount of magnesia determined in a solution obtained by extracting with cold water) we get :- -

$CaSO_4 2H_2O$	41·7
$MgSO_4 7H_2O$	4·0
$CaCO_3$	22·2
$MgCO_3$	18·5
*CaO	·9
*$(FeAl)_2O_3$	1·4
Residue	5·2
Moisture and Organic Matter	6·6
	100·5

Comparing this with the five analyses quoted above, it will be seen that the iron oxide and earthy matter has greatly increased, owing to the leaching out of lime and magnesium sulphates by the action of rain and fog.

---

* The CaO and $(FeAl)_2O_3$ uncombined here are possibly combined with the silica of the residue and with traces of Cl and P_2O_5.

Digitized by Google

Dr. W. Pollard.

In conclusion it must be stated that the alteration of the stone surface is to a great extent due to chemical causes, owing to the presence of sulphurous and sulphuric acids in the London atmosphere. These decompose the dolomite giving sulphates of lime and magnesia. The sulphate of magnesia, being a soluble compound, is to a great extent leached out and washed away by rain. The sulphate of lime, being a sparingly soluble compound, is leached out to a far smaller extent and tends to form a coating (with the soot, etc.) which helps to protect the stone. No doubt flaking or scaling play an important part in the weathering as well, but it is not possible here to calculate to what extent.

Suffice it to say that, with the exception of a few blocks which were of inferior quality and hence had decomposed to a greater extent, considering the time and conditions to which the stone had been exposed, the state was by no means unsatisfactory.

MINERALS FROM SKYE AND ROSS-SHIRE.

A black spinellid mineral, collected by Mr. Harker, was separated and analysed with the following results.

Mr. Harker gives the following account of its occurrence :—

"A black spinellid mineral from the peridotite group of the Cuillins. It occurs as small lustrous octahedra, making up practically the whole of certain seams, usually ½ to 1 inch thick, in the banded dunite of a small glen a little south of Allt a' Chaoich (the 'Mad Burn') near Loch Scavaig. The analysis shows it to be a Picotite. There are hitherto no analyses of this mineral from Britain."

SiO_2	1·19			
TiO_2	·34			
Al_2O_3	46·54	·4554	·6083	
Fe_2O_3	6·01	·0376		
Cr_2O_3	17·55	·1153		
FeO	10·10	·1403	·6027	
MnO	Trace			
(CoNi)O	·24			
CaO	·43	·0077		
MgO	18·35	·4547		
Total	100·75			

Omitting Silica, Titanic acid, Manganese and Oxides of Cobalt and Nickel, the ratio of RO : R_2O_3 works out to ·6027 : ·6083
or 1 : 1·01

The following is an analysis of the felspathic constituent of a Nepheline-Aegirine-Syenite-Pegmatite, a boulder from Coulmore, Ross-shire, collected by Mr. Hinxman.

*Portion of powder (separated by bromoform, diluted with xylene) of sp. gr. between 2·556 and 2·510.

* The powder was first treated with hydrochloric acid to remove nepheline.

Digitized by Google

		Mol. Ratios.	Dr. W. Pollard.
SiO_2	63·84	1·0570	
Al_2O_3	18·87	·1846	
*Fe_2O_3	·68	·0042	
CaO	·18	·0032	
K_2O	14·76	·1530	
Na_2O	1·23	·0198	
Loss on ignition	·30		
Total	99·86		

* State of Oxidation not determined.

This would represent—

$K_2Al_2Si_6O_{16}$	85·85
$Na_2Al_2Si_6O_{16}$	10·43
	96·28
Unaccounted for	3·58
	·86

The portion unaccounted for being composed of—

SiO_2 1·22 Al_2O_3 1·20 Fe_2O_3 ·68 CaO ·18
Loss on ignition ·30

TERTIARY IGNEOUS ROCKS FROM SKYE.

Three more Tertiary igneous rocks from Skye have been analysed. They were collected by Mr. Harker, who furnishes the following descriptions of them :— Mr. Harker.

8062 is an example of the innumerable sheets of basic rock referred to in former reports as cutting in an inclined direction the gabbro of the Cuillin Hills. It is a normal dolerite, bearing no close resemblance in composition to the gabbro. The locality of the specimen is Loch a' Bhàsteir.

9250 and 8732. Two closely associated rocks, forming one of a group of composite intrusions at Druim na Crìche, five and a half miles N.W. of Sligachan.

Each of these intrusions consist of two laccolitic masses in contact with one another ; the upper of an olivine dolerite (9250) with large porphyritic crystals of labradorite, the lower of a peculiar rock (8732) of more compact texture, which may be styled olivine andesite, its principal constituent minerals being oligoclase and olivine.

Digitized by Google

Dr. W. Pollard.

The analyses are as follows:—

	8062	9250	8732
SiO_2 - -	47·64	50·33	49·24
TiO_2 - -	1·27	1.81	1·84
Al_2O_3 - -	14·16	19·97	15·84
Fe_2O_3 - -	5·18	2·81	6·09
Cr_2O_3 - -	Trace	Trace	Trace
FeO - -	7·96	6·23	7·18
MnO - -	·33	·17	·29
(CoNi)O - -	Trace	Trace?	Trace
CaO - -	11·71	8·03	5·26
BaO - -	Not found	·06	·09
SrO - -	Not looked for	Trace	Trace
MgO - -	7·38	3·24	3·02
K_2O - -	·71	1·19	2·10
Na^2O - -	2·38	4·30	5·21
P_2O_5 - -	·09	·17	1·47
F - - -	Not looked for	Not looked for	·18
S - - -	·03	Not found	·03
H_2O at 105°	·19	·87	1·08
H_2O above 105°	1·44	·99	1·61
Total.	100·47	100·17	100·53
		Less O for F	·07
			100·46

ROCK FROM NEWLYN, CORNWALL.

Dr. Flett.

The following specimen, E3424, was collected by Mr. Clement Reid. The locality given is "Gwavas Quarry, near Newlyn Cornwall, 1″ 358, 6″ 74 S.W. Thick Sill (about 80′). Specimen from near the middle of the sill, and from the centre of a newly-broken block." Dr. Flett has examined the slice and gives the following description:—

E.3424. Gwavas Quarry, Newlyn, Cornwall.

Under the microscope this rock consists of actinolitic and tufted hornblende in small radiate groups of green needles, rather strongly pleochroic, and felspar, mostly plagioclase, but partly also untwinned alkali felspar. Much of the felspar is in large fairly idiomorphic crystals surrounded by smaller grains of irregular shape, so that the rock has a distinctly porphyritic character. According to the angles of symmetrical extinction the plagioclase is mostly an acid andesine. Grains of untwinned or simply twinned felspar (orthoclase or albite) are frequent in the groundmass surrounding the phenocrysts. In the larger nests and patches of actinolite there is a small amount of water-clear untwinned or simply twinned felspar which is probably albite. Iron oxides, leucoxene, and a few scales of biotite are the other ingredients. The actinolite may be regarded as having all formed from pyroxene, though no trace of the original outlines of this mineral can be found, and the clear albite appears also to be of new formation.

Digitized by Google

The analysis shows that the rock belongs really to the augite andesites or augite porphyrites. It contains too much silica and alkalies, too little lime and magnesia for a diabase. Even if all the lime is supposed to be present in the felspar (which cannot be the case as some is required for the actinolite) the ratio of lime to soda 3·71 to 6·52 would indicate a felspar of the oligoclase group. The original plagioclase is probably somewhat more basic than this (andesine), the rest of the soda being taken up in the albite and to a small extent in the orthoclase. Dr. Flett.

Sp. gr. 2·80 at 19°.

Dr. W. Pollard.

SiO_2	59·84
TiO_2	·64
Al_2O_3	15·71
Fe_2O_3	1·68
FeO	7·03
MnO	·12
CaO	3·71
MgO	1·37
K_2O	2·76
Na_2O	6·52
S	·10
P_2O_5	·20
H_2O 105°	·14
H_2O above 105°	·31
Total	100·13

BaO and Li_2O not found.

PSEUDOGAYLUSSITE FROM THE CLYDE.

Note on Crystals from the Clyde, analysed by Dr. Pollard.* Dr. Flett.

These crystals were obtained a few years ago by a dredging steamer engaged in deepening the channel of the Clyde near Helensburgh. They are dark brown in colour, resinous, transparent only in thin splinters, with a yellow streak and powder, no cleavage, and hardness about 3. The commonest are long prisms pointed at both ends, but without crystalline faces. The largest measures 5½ by ¾ inch. In transverse section these prisms are squarish or rhombic, but the angles vary considerably, and the roughness and rounded character of the faces do not allow of accurate measurements. On the best specimens small triangular facets cover the surfaces, their apices being directed from the edges towards the centres of the faces. The analyses show that they are impure carbonate of lime, the colouring matter being apparently organic, and the low specific gravity a consequence of a slightly porous structure. Microscopic sections showed that they have a distinctly zonal structure, and consist of little spherulites of fibrous calcite with occasional layers of parallel fibres between the spherulites and on the surface of the crystals.†

* Extracted from a paper read by Dr. Flett at the meeting of the British Association at Glasgow, September, 1901.

† For a full description of these crystals with an analysis, *see* Ch. O. Trechmann, "Ueber einen Fund von Ausgezeichneten Pseudogaylussit (=Thinolith=Jarrowit) Krystallen." *Zeitschrift für Krystallographie* xxxv., 1901.

Digitized by Google

Dr. Flett. Another mode of occurrence is in groups radiating from a centre. These may consist of as many as 40 or 50 individuals. The component crystals are smaller than in the previous cases, and have the barleycorn form of the well-known pseudogaylussite from Sangerhausen. The surface markings are similar to those described, but often the surface is honeycombed as if by corrosion. For specimens of these I am indebted to Mr. Renwick, Secretary of the Glasgow Geological Society.

Crystals of pseudogaylussite were obtained in excavations for the Jarrow Docks in 1857, and have been described by Professor Miers under the name of Jarrowite.* He agrees with Descloiseaux, Williams, and Dana that they are in all probability pseudomorphs after celestite. In this case tests for barium and strontium gave negative results, and a large clay nodule full of these crystals, forwarded by Mr. Renwick, proved to consist of carbonates of lime and iron mixed with clay, and did not contain strontium in determinable quantity.

Dr. W. Pollard. The crystals (from the Clyde) of pseudogaylussite which were analysed in this laboratory were sent to Mr. Rudler by Mr. John Paton, of Glasgow.

The analysis gave the following values:—

CaO	47·93	
MgO	4·21	
CO_2	39·91	
P_2O_5	2·23	
Loss at 105°	3·13	
Loss above 105° (to ignition)	2·81	= Water and organic matter.
Residue insol. dil. HCl.	·11	
	100·33	

Traces of iron, manganese, chlorine, and sulphate also found.

No nitrogen found. Carbon of organic matter about 1·2%. Calculating as carbonates and phosphates,

$Ca_3(PO_4)_2$	4·87	
$CaCO_3$	80·88	
$MgCO_3$	8·28	
MgO	·25	not accounted for.
	94·28	

The specific gravity was found to be

On a crystal fragment 2·55
Powder in pyknometer 2·57 } at 23°

Dr. C. O. Trechmann [*Zeitschrift für Krystallographie*, xxxv., p. 283, 1901] found

2·575 at 18·5° C. in coarse powder,
2·602 at 16·5° C. in fine powder,

for some crystals from the same locality.

* "On some British Pseudomorphs," by Prof. H. A. Miers, *Mineralogical Magazine*, 1897, xi., p. 264.

Digitized by Google

The composition of these are quoted below, for comparison with those analysed here:— Dr. W. Pollard.

	Dr. C. O. Trechmann.	M.P.G.
$Ca_3(PO_4)_2$ - - -	5·52	4·87
$CaCO_3$ - - - -	83·52	80·88
$MgCO_3$ - - - -	9·03	8·28

This appears to show that the composition of the different crystals may vary, but the agreement is as close as may reasonably be expected in the case of pseudomorphs of this nature.

IV. PALÆONTOLOGICAL WORK.

The ordinary duties of the Palæontological Department in relation to the maintenance of the collection of fossils in the Museum of Practical Geology, and the detailed work necessitated in the registration and determination of the fossils received from the officers in the field and otherwise, although making the first, and a large, demand upon the time of the officers, call for little notice in this place. Some 800 new specimens have been added to the collection already in the Museum, and a large amount of revision has been accomplished, necessitating in some instances a rearrangement of the cases. Mr. E. T. Newton.

The large series of Echinodermata and Phyllocarida from Palæozoic formations, and the plants from the Inferior Oolite and other Jurassic strata, have been revised by Mr. H. A. Allen, who has taken advantage of this opportunity to prepare a catalogue of all the figured and type specimens in the first two of these groups, which this institution possesses, thus continuing the very useful piece of work begun some two years ago (*see* Appendix, p. 200). A similar catalogue of the Pliocene and Pleistocene figured specimens was prepared by the same officer early in the year, but, being ready, it was deemed expedient to publish it in the Appendix of the *Summary of Progress* for 1900.

The Carboniferous Cephalopoda, contained in the Museum cases, have undergone a similar revision by Dr. F. L. Kitchin, whose time has been largely occupied during this year with the determination of the large series of fossils collected by Mr. G. W. Lamplugh from the trial borings at Brabourne and Penshurst, as well as from the shaft at Dover. Dr. Kitchin has paid several visits to Dover in order to watch the progress of the shaft being sunk through the Jurassic strata, and has himself obtained representative collections of the fossils from the various horizons passed through.

The examination of the Devonian fossils collected by Mr. W. A. E. Ussher, and mentioned in last year's *Summary of Progress*, has been completed, and a preliminary report prepared. The occurrence at certain localities in the neighbourhood of Looe, and at other places in the Torquay promontory, of such fossils

Digitized by Google

Mr. E. T. Newton.

as *Spirifera primæva*, *Orthotetes hipparionyx*, and *Pleurodictyum problematicum*, and the further recognition at still other places of *Strophomena latecosta* (= *Tropidoleptus rhenanus*), *Rensselæria strigiceps*, *Orthotetes hipparionyx*, and *Homalonotus*, seem to demonstrate that the Looe fauna occurs in the Torquay promontory. Certain of the characteristic fossils are likewise met with in the intermediate area. The fragmentary nature of the fossils makes the determination of the horizons somewhat uncertain; but Mr. Ussher has hopes of being able, by their means, to correlate the Devonian horizons in a large part of this difficult and disturbed district.

Three or four small sets of fossils were received from Mr. G. Barrow, from the promontory of Suishnish, between Loch Slapin and Loch Eishort, south of Broadford, Skye, where he was anxious to trace the upper limits of the Lower Lias, and possibly the base of the Middle Lias; but all the determinable fossils pointed to the beds belonging to the zone of *Ammonites Jamesoni*, and there was nothing that could be clearly referred to the Middle Lias at this locality.

A series of specimens of Cherts and other rocks from Alt nan Leac, Soay Sound, South Skye, have been examined; these were forwarded by Mr. C. T. Clough, who thought they might be of Cretaceous age. Some of the Cherts had been found *in situ*, others in the volcanic agglomerate of the district; and they resemble in appearance certain of those which had been discovered in Arran. Several slices were prepared, which showed, in the first place, that the rock *in situ* was similar to that in the agglomerate. In all these Cherts organisms are present, but they are much obscured by chalcedonic deposits. Sponge spicules seem to have been very abundant, but have become decomposed. Foraminifera are present, Textularian forms being most numerous, but *Globigerina* seems also to be represented. Some of the sections show fragments of Echinoderm plates and pieces of Serpula. These Cherts are unlike those from Arran, but support Mr. Clough's opinion of their Cretaceous age; it is thought, however, that these rocks have more the appearance of Greensand Cherts than of altered Chalk—an opinion which Dr. G. J. Hinde has been good enough to confirm.

A series of plants, collected some years ago from the Reading Beds in the Waterloo Brickyard, Reading, have been recently re-examined for the purposes of the Memoir on this district, written by the late J. H. Blake, and now being prepared for publication by Mr. H. W. Monckton. The following forms are believed to be present, but their determination can only be taken as approximately correct:—*Anemia subcretacea*, *Acer* sp., *Aralia* near to *looziana*, and *Laurus* resembling *L. Jovis*. There are likewise slender leaves like *Salix;* the base of a leaf like *Litsaea;* and a fragment with venation like *Viburnum*.

Digitized by Google

Mr. E. T. Newton.

The following is a list of the specimens in the Museum of Practical Geology, figures of which have been published during the year :—

Palæontographical Society's volume for 1901 :—

By Miss Elles and Miss Wood :

Didymograptus hirundo, Salter.
" *v-fractus* var, *volucer*, H. A. Nicholson.
" *gibberulus*, Nicholson.
" *deflexus*, n. sp.
" *nanus*, Lapworth.

By Dr. Wheelton Hind :

Leiopteria Thompsoni, Portlock. Four specimens.
Actinopteria persulcata, McCoy. Three specimens.
Pteronites latus, McCoy.
Posidonomya Becheri, Bronn. Three specimens.

By R. H. Traquair :

Elonichthys Aitkeni, Traquair.

By H. Woods :

Trigonia scapha, Agassiz.
Spondylus striatus, Sowerby.
" *dutempleanus*, d'Orbigny.
Plicatula placunea, Lamarck.

Geological Magazine for 1901 :—

By H. A. Allen :

Fouquea cambrensis, n. sp.

V. MUSEUM OF PRACTICAL GEOLOGY.

Mr. F. W. Rudler.

Among the most notable donations is a large collection of polished Indian Agates, presented in the early part of the year by Mr. Lennox Boyd. Attention may also be called to a series of minerals from Victoria, presented by the Department of Mines through the Agent-General.

In view of the removal of the offices of the Geological Survey, on the expiration of the tenure of the adjacent premises in Jermyn Street in the course of the present year, measures have been taken to provide for the accommodation of the officers of the Survey in the Museum building. This has necessitated considerable alterations in the arrangement of the Museum. The collections of Pottery, Porcelain, Glass, Enamels and Mosaics have been removed, partly to the Victoria and Albert Museum at South Kensington, and partly to the Branch Museum at Bethnal Green. The space thus gained is being fitted up as a Petrographical Department, to which the rock specimens at present exhibited in a room on the Upper Gallery of the Museum, will shortly be transferred.

The contents of the two Model Rooms have also been removed, and such of the models as illustrate British Geology are now exhibited on the principal floor of the Museum, where space has been obtained for their display by the removal, to the Alexandra

Digitized by Google

Mr. F. W Rudler.

Palace, of several cases of specimens illustrating the application of metals to various purposes of industry and art.

The Library has received many valuable additions during the year, and the collection of Geological Photographs has also been largely augmented. An extensive collection of the Maps and Sections of the Geological Survey of Great Britain and Ireland has been transferred from the Survey Office to the Library, where visitors desirous of consulting them will find them more convenient of access. Progress has been made in the work of removing from the Library those works which are not strictly Geological in character; and during the past year upwards of 7,000 volumes have been transferred to the Science Library of the Victoria and Albert Museum.

VI. MAPS, SECTIONS, AND MEMOIRS PREPARED AND PUBLISHED.

The following is a List of the Maps, Sections, and Memoirs issued by the Geological Survey of England and Wales during the past year :—

I.—MAPS.

One-inch Maps (New Series).

Sheets 261 and 262 (Bridgend), in one map. Two editions, with and without Drift. By R. H. TIDDEMAN and T. C. CANTRILL.

One-inch to four miles (Index) Map.

New Editions.

Sheets 8 and 11 revised. Sheet 12 reprinted.

Six-inch Reference Maps.

49 MS. coloured copies of six-inch sheets and quarter-sheets have been made from the field copies, and deposited in the Office for public reference. These are as follows :—

Berks.—9 N.W., N.E., S.W., S.E.; 16 S.W.
Brecon.—37 N.W., S.W.
Bucks.—41 N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.
Carmarthen.—35 S.W.; 42 N.E., S.E.; 43 N.W., S.W.
Dorset.—21 S.E.; 31 S.W.; 40 S.W.
Glamorgan.—7 S.E.; 8; 14 N.E.; 15; 24.
Leicester.—18 N.W., N.E.; 19 S.W.; 27 S.W.; 33 N.E.; 38 N.E.
Oxford.—40 N.W., N.E., S.W., S.E.; 45 N.W., N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.; 50 N.W., S.W.
Rutland.—4 N.E.
Wilts.—69.

II.—VERTICAL SECTIONS.

Three Sheets of Vertical Sections have been published.

Sheets 84 and 85 of Shafts in the South Wales Coalfield.
Sheet 86 of Shafts in the North Staffordshire Coalfield.

Digitized by Google

III.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom" for 1900, pp. 221. Price 1s.

"Guide to the Geology of London." By W. WHITAKER. 6th edition. pp. 102. Price 1s.

List of Extra-official Publications.

ALLEN, H. A.—"On an Insect from the Coal-Measures of South Wales." *Geol. Mag.*, 1901, pp. 65–68.

GIBSON, W.—"On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire; and their Relation to the Productive Series." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 251–265.

HILL, J. B.—"On some Geological Structures in West Cornwall' *Trans Royal Geol. Soc. Cornwall*, vol. xii., part vi.

NEWTON, E. T.—"British Pleistocene Fishes." *Geol. Mag.*, 1901. pp. 49–52.

————"Graptolites from Peru." *Geol. Mag.*, 1901, pp. 195–197.

STRAHAN, A.—"On the Passage of a Seam of Coal into a Seam of Dolomite." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 297–304.

————"An Abnormal Section of Chloritic Marl at Mupe Bay, Dorset. *Geol. Mag.*, 1901, pp. 319–321.

TIDDEMAN, R. H.—"On the Formation of Reef Knolls." *Geol. Mag.*, 1901, pp. 20–23.

USSHER, W. A. E.—"The Culm-measure types of Great Britain." *Trans. Inst. Mining Engineers*, vol. xvii.

WEDD, C. B.—"On the Corallian Rocks of St. Ives (Huntingdonshire) and Elsworth." *Quart Journ. Geol. Soc.*, vol. lvii., pp. 73–83.

WOODWARD, H. B.—"Note on a Phosphatic Layer at the Base of the Inferior Oolite in Skye." (*Brit. Assoc.*) *Geol. Mag.*, 1901, pp. 519, 520.

II. SCOTLAND.

I. FIELD WORK.

Dr. Horne reports that in the northern district in charge of Mr. Gunn the work of the survey has been continued in the northern part of Inverness-shire and in the central and eastern parts of Ross-shire, as well as in a small portion of the county of Sutherland. Work was carried on in one-inch sheets 61, 71, 72, 83, 92, 93 and 102, and of these 71 and 92 are reported as completely surveyed.

1. NORTHERN DISTRICT—INVERNESS-SHIRE, ROSS-SHIRE AND SUTHERLANDSHIRE.

Mr. W. Gunn, District Geologist.

Mr. C. T. Clough
Mr. L. W. Hinxman
Dr. C. B. Crampton
} Geologists.

Digitized by Google

The location of the staff was as follows:—

Mr. Clough worked in the parish of Glenelg in the western part of Inverness-shire: Mr. Hinxman in the Inverlael Forest and near Loch Garve in central Ross-shire, and in the northern part of Inverness-shire: Dr. Crampton in the Strathvaich and Inverlael Forests in central Ross-shire, and in the Strathrusdale district of East Ross-shire: Mr. Gunn in the Fannich and Strathvaich Forests of central Ross, in the Loch Broom district of the same county, and on the shores of the Dornoch Firth. The Assistant Director, Dr. Horne, completed the survey of some small portions of ground in the Fannich Forest.

METAMORPHIC ROCKS.

Mr. Clough.

Mr. Clough's work on the oldest rocks lay in two detached districts: (1) between the S.E. side of Loch Duich and the head of Glenelg; (2) near Inverguseran.

Glenelg.—In district (1) the oldest rocks belong to the Lewisian gneiss formation and the Moine schists. Among the members of the first formation were found marble, garnetiferous kyanite, biotite schist, hornblende schist, eclogite, and serpentine. Biotite schist forms most of the area between Balvraid and Loch Iain Mhic Aonghais. It is supposed to be an altered sediment of approximately the same age as the limestone, and it differs from the micaceous schist of the Moine formation in the same neighbourhood in various respects, particularly in containing thin streaks and lenticles of dark hornblende schist, and granulitic pale-grey quartz-felspar material, which has, perhaps, been formed from old pegmatites.

The Moine rocks occupy a considerably larger area than that of the Lewisian gneiss. In respect of composition they are generally divisible into two classes, one of more siliceous character than the other; but there are rocks of intermediate type, and it is not clear that all the rocks of one type are on one horizon.

The bands next to the Lewisian gneiss are in some places of the siliceous and in others of the more micaceous type. On the E. slope of Beinn Aoidhdailean is a thin strip of Lewisian gneiss, at the W. margin of which the Moine rocks are generally of the micaceous type; while on the E. margin, for about a mile along the strike, there is a band of siliceous schist. The phenomena might give the impression that we have here an unfolded succession of three rocks, in which the Lewisian gneiss occupies the middle position. It is, however, more probable that the gneiss occurs in the middle of a long-limbed isocline. The difference in the characters of the beds on either side now seems startling in view of the short distance between them, but we must remember that this distance may be much less than that which once separated the areas of formation of the beds. It has often been noticed, also, that as we follow some straight junction-line between the Moine rocks and the Lewisian gneiss, both these rocks vary considerably in character.

Digitized by Google

Mr. Clough.

The Moine rocks show different stages of alteration in different districts. In many places they are represented by veined gneisses, in which half of the rock is composed of thin lenticles and streaks of pegmatite, while in the other half the minerals developed are unusually large. Veined gneisses, partly of a siliceous and partly of a micaceous type, are well seen in the following places: between Strath Chomair and Biod an Fhithich, at the Creagan Dubh of Ghleann Aoidhdailean, the top of Sgurr Mhic Bharraich, and on the watershed extending S. of this hill for two miles or so. Besides the thin pegmatites above referred to, which are repeatedly folded with the beds, there are, in certain areas in which the rock is not always veined with thin pegmatites, many thick, well-defined bands of pegmatite, as much as 50 yards broad, which cross both the Lewisian gneiss and the Moine rocks. These bands are later than the thin folded pegmatites, and they often cross quartz veins and beds which have previously been intensely folded. In one locality some of the bands have been sheared and partly granulitised.

After the Lewisian gneiss and the Moine rocks had been invaded by pegmatites and folded, they were pierced by a series of intrusive rocks, which we may call the Glenelg-Ratagan complex.* The largest outcrop of these rocks extends from near Suardalan rather more than three miles in a N.N.E. direction, and the average breadth is two miles. Wherever they are seen, the outer margins of the main mass and the minor outcrops are very jagged, and formed of rocks which are quite unchilled.

In the field the rocks can be roughly divided into three groups, each of which includes several varieties, that seem to pass into one another, and in certain places the rocks of one group also pass gradually into those of another. The groups are as follows:—

A. Biotite granite (or granitite), biotite hornblende granite, pale syenite.

B. Dark syenite, augite syenite, mica augite diorite.

C. Pyroxenite, biotite pyroxenite, hornblendite.

The rocks of the ultrabasic group C. contain a small proportion of orthoclase. The syenite in group A. contains a very small proportion of the ferromagnesian constituents, and a little quartz.

On the W. side of the complex there is a granite, which passes gradually eastwards through Tonalite into Diorite, but farther E. the rocks of group A., including a granite of somewhat different character from that at the W. side, often intrude into, and include portions of rocks in group B. In one place rocks of group B. clearly intrude into others of group C., and we infer that they often do so from the numerous inclusions of pyroxenite, &c., they contain.

The dark syenites and diorites often show flow structures, and sometimes have such a prominent banding that they might be

* The E. portion of this complex has not yet been surveyed.

Digitized by Google

Mr. Clough. taken for Lewisian gneisses. Short strings of granite or granite porphyry, irregular in direction and without chilled margins, frequently cross the banding.

The rocks of groups A. and B. are in some places sheared in thin nearly vertical bands, which have been thoroughly granulitised. These are never more than a few feet thick, but in some places, *e.g.*, on the coast half a mile N.W. of Ratagan, they are so crowded that they form a considerable proportion of the rock.

In and near the complex there are some dark basic dykes, which are foliated and cut by strings of granite porphyry. One of these dykes is called by Dr. Flett a mica diorite. A considerable number of unfoliated dykes, including quartz felsites, porphyrites and mica traps, pass through rocks of the complex, and have thoroughly chilled margins. Their general direction is W.N.W.

(2).—*Inverguseran.*—In this district nearly all the rocks belong to the Moine series, but near Rudh' Ard Slisneach there are also small patches which may be grouped with the Lewisian gneiss.

In no place have the Moine rocks been converted into veined gneisses, but many of them, especially the more micaceous, are crowded with small spots, usually from $\frac{1}{8}$ to $\frac{1}{16}$ inch in diameter, of secondary felspar, apparently albite. A broad zone of garnetiferous mica-schist, which is well exposed on the coast near and S. of the village of Airor, contains a good many impure calcareous lenticles and thin calcareous beds, rarely more than a few inches thick, which still show clastic grains more than half an inch long, chiefly of quartz. The zone has a considerable resemblance to the Loch na Dal series,* but is in a much more altered condition.

The igneous rocks are all dykes, and later than the period of foliation and folding of the schists. They may be divided into three groups—

1. Diorite.
2. Mica traps and lamprophyres.
3. Rocks of Tertiary age. (These are described elsewhere, *see* p. 114.)

The two first groups are of small extent and their relations are doubtful. The general direction of the dykes of group 2 is nearly E. and W.

Physical and Economic Features of the Glenelg Districts.—The area surveyed near Loch Duich and in Glenelg is for the most part of a wild hilly character, but the igneous complex already described forms an exceptionally green smooth tract, and a considerable part of it is said to have been under the plough about 80 or 90 years ago. Most of the rocks of the igneous complex disintegrate readily, and give rise to soils which are presumed to be rich in alkalies, and perhaps also in apatite—a mineral which is a noticeable macroscopic constituent of the rocks.

* The lowest series but one of the Torridonian rocks of Skye.

Digitized by Google

Near the head of the Glenbeg of Glenelg there is a vein of galena, about four inches broad, but it is only seen in the stream-bed. Mr. Clough.

The largest peat moss, occupying perhaps a quarter of a square mile, lies about three-quarters of a mile W. of Suardalan, but being some distance off any house, it is not cut for fuel. Most of the shepherds have peat near their own homes, which is generally of excellent quality, though sometimes in small patches. In a peat moss rather more than half a mile N.W. of Bealachachasain there is a sulphur well, which once had considerable fame, but it is not so strong as formerly.

All the hill ground is pastoral, but on the side of Loch Duich, and near some of the houses, there are a few ploughed fields. The population is very sparse, and the ruins of several crofter hamlets are noticeable in the Glenmore of Glenelg. Near Inverguseran the 100-feet raised beach was formerly under cultivation, both along the shore and in the glen, and a small part of the same beach is still cultivated near Airor. The gravel in the present and the 20-feet raised beach near Inverguseran is very clean, and the pebbles in it are for the most part hard and siliceous. It is occasionally shipped for use in gardens in more populous districts.

With the exception of five isolated houses, most of them occupied by shepherds or keepers, the population is confined to the picturesque hamlet of Airor. There is a good natural harbour here, and the people make their living partly by fishing.

Fannich Forest.—In the autumn Mr. Horne completed the small patches of unsurveyed ground at the head of Loch Fannich, Ross-shire.

Part of this area lies to the north of Loch Fannich and along the south side of the Fannich watershed, extending from A'Chailleach (3,276 feet) by Sgurr Breac to Sgurr nan Clach Geala (3,581 feet). The various groups of crystalline schists identified and traced by Mr. Gunn on the N. side of the Fannich mountains (*Summary of Progress*, 1897, p. 38; 1899, p. 10) have been followed southwards to Loch Fannich and the hills beyond. A description of the geological structure of the south portion of the Fannich group, so far as the lines had then been traced by Mr. Horne, appeared in the *Annual Summary*, 1898, p. 11, and 1899, p. 8. In the latter Report (pp. 8 and 9) reference is made to the occurrence of a belt of acid gneiss with basic bands and lenticles of epidiorite and hornblende schist, resembling certain types of Lewisian gneiss, which belt, in the western part of the Fannich group is both underlain and overlain by garnetiferous muscovite-biotite schist. During last autumn the boundaries of this belt were traced from the watershed between Sgurr Breac and Sgurr nan Clach Geala southwards by Torran Ruadh to near the north shore of Loch Fannich, and westwards by the mouth of Allt nah-Ara, 1¼ miles east of Cabuie, towards the Nest River (Abhuinn Nid). Along the line of junction with the underlying and overlying muscovite-biotite schist, where there probably was considerable differential move- Dr. Horne.

Digitized by Google

Dr. Horne. ment, the acid gneiss shows marked linear foliation, with "eyes" of felspar, and resembles the granulitic schists of the Moine type. In places, however, it is coarsely granulitic, highly quartzose, with muscovite and biotite. The distinctive feature of the belt is the presence of basic bands, sometimes massive with hornblende and plagioclase felspar, and sometimes foliated, which transgress the foliation planes of the acid gneiss. One of these has been traced for a third of a mile on the south slope of Creag nah-Ara east of the head of Loch Fannich, and another for half a mile southwards, from the head of Allt Leac a' Bhealaich.

The muscovite-biotite gneiss with thin pegmatites and lenticles of garnetiferous hornblende rock that overlies the belt of acid gneiss just described, forms the crest and south slopes of A'Chailleach and of Sgurr Breac; it is exposed in Allt Leac a' Bhealaich and is continued southwards in Sail Mhor to Creag nah-Ara near the head of Loch Fannich. An examination of the crags on the south slope of Sgurr Breac and also on Sail Mhor reveals the puckering and overfolding of the muscovite-biotite gneiss.

Another patch of ground completed in the autumn lies about three miles to the west of the head of Loch Fannich and to the north of the Cabuie River, where the rocks consist of granulitic quartzose schists of the Moine type with a zone of biotite schists. The latter has been traced from the watershed at the head of Allt a' Chleibh southwards to the Cabuie River, and is probably the western prolongation of the Sgurr Mòr Fannich band.

Mr. Gunn. The small area completed by Mr. Gunn in the Fannich Forest lies mainly on the south and east sides of Beinn Liath Mhòr Fannaich, and the ground is nearly all above the 2,000 feet contour. The schists of this area are of the usual quartzose Moine type, with occasional thin bands of biotite schist. These rocks are bounded on the west by the thick mass of biotite schist which forms Sgurr Mòr. The rocks are intensely folded, the axis of the folds trending beween north-west and north, and the dip of the folds being to the west. This is the structure of the southern inclination of the part of the area adjoining Abhuinn a' Ghiubhais Li', but as we follow the rocks northward the folds become vertical, or nearly so, and strike due north, the strike gradually trending to the east of north, and the steep-sided folds dipping easterly.

Mr. Hinxman *Ross-shire.*—The ground between Loch Garve and Strathconon (Sheet 83), on which Mr. Hinxman was engaged during the month of April, is for the most part bare and rocky, and the geological structure extremely complicated. The siliceous Moine schists and the coarse muscovite biotite gneiss by which the ground is chiefly occupied are interfolded in a most intricate manner; while between Tarvie and Strathconon there is, in addition, a great development of garnet-amphibolite, an intrusive rock which shares in the folding of the schists.

The basic rock occurs in more or less continuous sills and lenticular masses. These are thoroughly foliated with the schists, but are usually coarser and more felspathic in their central portions. Near the edge of one of these intrusions at

Digitized by Google

Comrie, where the mass is upwards of 300 yards in breadth, a thin band of ferriferous calc-biotite schist occurs, apparently along a line of crush. The edge of this sill shows a somewhat unusual modification of the igneous rock, probably due to the absorption of material from the contiguous schists. It contains, according to Dr. Flett, a little quartz and orthoclase in addition to the usual biotite and plagioclase, besides large masses of ferriferous carbonates, and plates of iron oxide. Crush lines are also frequent in the Moine schists, and are sometimes accompanied by bands of breccia two or three feet in breadth, made up of angular fragments of the adjacent rock. Mr. Hinxman

Inverness-shire.—The area between Glen Strathfarrar and Glen Cannich, surveyed during the summer and late autumn months, is entirely occupied by schists and flagstones of "Moine" type, and garnetiferous muscovite biotite gneiss; both similar in lithological character to the rocks farther to the north and east that have been fully described in former reports.

Though there is evidence of a considerable amount of folding—especially in the lower part of Glen Cannich, and near Deanie Lodge in Glen Strathfarrar—it is on the whole of a less complex character than that found in Strathconon.

The muscovite biotite gneiss is largely developed in the western part of the area, and forms broad and well defined belts that can be traced continuously for some distance, and give rise to the more rugged features of the mountains in the Broulin and Glen Cannich forests. The general strike of the schists in this region is—neglecting minor flexures—between N.N.E. and N.E., while the limbs of the isoclinal folds usually dip to the east.

On the north side of Glen Cannich, in the south-west corner of Sheet 83, the rocks form a part of a broad anticlinal fold, on either side of which the dip is to S.W. and S.E. respectively.

The siliceous schists and flagstones of the Moine series largely predominate in the district east of Strathglass, between Glen Urquhart and the Beauly River, and the original argillaceous sediments are only represented by thin bands of biotite-muscovite schist, characterised by large "spangles" of white mica. Some of the highly siliceous schists are crowded with small pale-coloured garnets.

The zone of amphibolite sills which crosses the river Farrar at Struy, has been followed southwards along the western side of Strathglass as far as the foot of Glen Cannich. They present the usual character of these intrusions. Two of these sills are cut, a short distance west of Glassburn, by a vein of coarse muscovite pegmatite. At the point of intersection both this vein and the basic sills, as well as the surrounding siliceous schist, are highly garnetiferous.

With the exception of a few thin dykes of lamprophyre and mica-trap there appear to be no igneous intrusions in the rocks to the west of this zone; though the usual knots and veins of pegmatite and quartzo-felspathic material, probably of segregative origin, are abundant, particularly in the coarser gneisses. One of these pegmatite veins on the shore of Loch Mullie, contains crystals

Digitized by Google

Mr. Hinxman

of tourmaline. The later dykes, referred to above, have a persistent east and west trend, and though never more than a few feet in breadth, can be traced for considerable distances, in two instances for more than three miles. In a specimen taken from one of these dark Minette dykes above the farm of Mid Crochail, Strathglass, Dr. Flett has detected the presence of a sky-blue secondary amphibole deposited on the surfaces or in the cracks of brownish-green hornblende, and in optical continuity with the primary mineral. The occurrence of secondary blue amphibole in crystals of hornblende has previously been noted by Flett in a lamprophyre from the Orkney Islands, and by Seymour in a hornblende-kersantite from Co. Down, Ireland.*

A parallel system of north-east and south-west faults, one of which has probably defined the straight course of Strathglass, traverses the ground on the east side of that valley. The relations of one of the mica-trap dykes to these faults show that the latter are of different ages. The position of the dyke is shifted by two of these faults, but in a third case it has been intruded along the line of weakness produced by the dislocation, and bending sharply from its former easterly course, follows the north-east trend of the fault for a distance of half a mile. This portion of the dyke contains numerous included fragments of the fractured schists, none of which appear in it outside the fault.

Ross-shire.—The area mapped by Mr. Hinxman during the month of June in the Inverlael forest, is occupied by siliceous schists and flagstones of the regular "Moine schist" type, with occasional bands of dark biotite schist, often garnetiferous. The latter vary from a few inches to (rarely) thirty or forty yards in breadth, and in some cases give rise to well-marked cliff features on the mountain sides. These rocks are evidently the altered representatives of a homogeneous mass of arenaceous sediments, probably of the nature of an arkose, with a few thin bands or seams of argillaceous material.

A line drawn nearly due north through Meall nan Ceapraichean and Eididh nan Clach Geala, indicates the position of an axis of plication along which the beds are suddenly rucked up into sharp asymmetrical folds, one limb of the fold being nearly horizontal, while the other may be vertical or even slightly overfolded.

Another zone of extreme plication crosses the summit of Meall Dubh, three miles N.N.E. of Inverlael. The overfolding is here far more pronounced, and the limbs of the folds often appear to be lying horizontally and parallel to one another. The structure of the ground between these two lines is generally simple. The beds dip at uniformly gentle angles, in directions varying from east by north round to south by west. This appearance of regularity is however possibly deceptive, for even where the beds seem to be arranged in regular succession, the crests of flattened overfolds can sometimes be detected,

* H. J. Seymour. "Occurrence of a Blue Amphibole in Hornblende Kersantite." *Geol. Mag.*, Dec. 4, vol. vii., p. 257.

Digitized by Google

and it is thus possible that only a small thickness of rock may be involved in the plications that cover a wide area. Mr. Hinxman

No igneous intrusions have been found in these rocks, but they contain frequent thin veins of quartz, and a few veins of pegmatite, both probably of segregative origin.

In the Allt na Lairige near its junction with the Douchary river, and also in the latter stream north of Creag Dubh, there are veins of quartz with which is associated a little plagioclase, felspar and a green pleochroic pyroxene which resembles ægirine augite. The pyroxene occurs in strings or amorphous masses in the quartz and also in isolated idiomorphic crystals.

Physical and Economic features.—The greater part of the area surveyed by Mr. Hinxman during the past season is wild mountainous ground, almost entirely given up to grouse and deer. The cultivated areas are confined to the alluvial stretches along the larger streams, and the grouse moors support a certain number of sheep during the summer, but the amount of good grazing ground is very limited.

Owing to the hard siliceous nature of most of the rocks and to subsequent glacial action, there is over the area occupied by the Highland schists little or no surface soil due to disintegration. The corries and higher parts of the glens are, however, often filled to a considerable depth with stony morainic drift, which is not as a rule favourable to vegetation.

The thin dykes of Minette which traverse the schists in Strathglass decompose readily into an orange-red soil, which, from the abundance of apatite in the rock, is peculiarly fertile, and gives rise to stripes of vivid green herbage that stand out in striking contrast to the surrounding barren schists. The lower ground in Kiltarlity and at the head of Glen Urquhart is more fertile, and much of it is under cultivation. The soil is here derived from drift deposits, usually loose and gravelly above, but passing downwards into stiff boulder clay.

Beyond a few small openings, for local purposes, in the flagstones of the Moine schists there are no quarries in the district surveyed.

Large areas on the hill slopes and in the higher valleys are occupied by peat mosses, often of considerable depth. The peat is dug to a small extent for fuel where it is fairly accessible, and may be of considerable economic importance in the future.

The population is sparse, very scattered, and confined to the valleys. Water supply is abundant, of excellent quality, and far in excess of the requirements. The potential water power represented by the numerous natural reservoirs, streams, and falls in the district, is very great, but has not, so far, been made use of.

The sides of the larger valleys are well clothed with natural woods of pine and birch, with oak on the lower slopes. In Glen Strathfarrar the pine grows well, up to an elevation of over 1,100 feet above sea level. Large areas in Kiltarlity have been planted with coniferous trees, and there are also smaller fir plantations at the foot of Glen Orrin and in the higher parts of Strathconon. The natural wood flourishes well on rocky slopes

Digitized by Google

Mr. Hinxman

where the soil is scanty, and there is no doubt that large areas of the ground under 1,000 feet in elevation, that are now barren moorland, but are shown by the remains in the peat mosses to have been once thickly clothed with forest, might be profitably replanted.

Mr. Gunn.

Ross-shire.—The work done by Mr. Gunn in the Loch Broom area offers few points of interest apart from that of previous years, in the same district. For the most part the rocks belong to the siliceous Moine type of crystalline schists, the foliation of which dips at comparatively low angles of 10°–20° to points between south and south-east. The rock is generally flaggy and the dip is fairly regular over large areas. Folds or plications can seldom be detected, though good outcrops in scars and in burn sections are numerous.

On the south side of the Lael Valley, at its head, sharp folds trending somewhat east of north are extremely numerous, but as we pass westward down the valley, they disappear in the course of a mile or so, and we find a series of quartzose schists dipping regularly to the southwest at about 20°. The dip gradually changes so as to become due south about Glensguaib, and then east of south, which is the general direction along the valley of Loch Broom.

The structure of the ground for a long distance north of the Lael is similar to that south of this river, but as we approach Meall Dubh, where there are bands of biotite schist, we again find the rocks much plicated. To the northward of this hill, the beds again appear regular and the strike curves round, as along the Lael, being north-east at Leckmelm and south-east near Douchary.

The line of Coire Granda to the east of Beinn Deirg, nearly coincides with the axis of a large anticlinal fold which dies out to the northward in a series of rapid plications. To the east of this corrie for a long distance, the siliceous Moine-schist with occasional thin bands of biotite schist dip steadily in a north-easterly direction, which gradually changes to an easterly dip along the east side of Allt Lair, and the beds are comparatively free from visible folds.

Dr. Crampton

The ground on which Dr. Crampton was engaged during the month of June, is that part of the Inverlael Forest lying around the head of the Douchary River. It is difficult to reach, and the greater part of it is more than 2,000 feet above the sea. There is no population or cultivation of any kind on this ground, the whole area being very rugged and rocky, and under deer.

The crystalline schists are principally quartzose schists with varying proportions of micas. They are sometimes of a flaggy character, but mostly heavy gneisses, breaking up into large blocks. Alternating with the quartzose bands, are thin bands of a wavy bluish biotite schist, often containing garnet. They are largely developed on Meall a' Coire Glais and Tomain Coinich. Bands of garnetiferous mica schist, with larger proportions of muscovite, occur about the head of Chadha Dheirg, and on the eastern slope of the hollow leading thence to the head of

Digitized by Google

the Glen Beag stream. Over the N.E. flank of Seana Bhraigh the rocks dip S.S.E. at angles of 15°–25°, and there is little folding to be seen. The rocks also dip at low angles, but due E. on Meall a' Coire Glais, while further to the south, round the Lochan Sgeirich, the dip is E.N.E. at angles of 20°–30°. Throughout these districts small escarpments and dip slopes are common features and the dips are constant over wide areas, but further east about the head of Chadha Deirg, and between this and Sron an Tomain Coinich, the folding begins to be marked, and contorted folding is beautifully shown in Creagan Tomain Coinich and the cliffs at the eastern end of Chadha Dheirg. Dr. Crampton

Strathvaich.—The part of the Strathvaich Forest, surveyed by Dr. Crampton from his station at Aultguish Inn lies between the Glascarnoch River and the Strathvaich River, and stretches northward along the west side of Strathvaich as far as Loch Toll à Mhuic.

The crystalline schists form nearly the whole of this area. They are chiefly granulitic quartzose rocks of the Moine type, with subsidiary bands of muscovite-biotite schist.

Along the western slopes of Strathvaich the strike of the rocks is almost due N. and S., but north of Aultguish Inn it becomes S. 10 E. —N. 10 W., and this is continued over Meall an Torcain, Tom Ban Mòr, and the heights further to the north. The folding of these schists is nearly vertical in the eastern part of the district, the dip being sometimes westerly sometimes easterly, but always at high angles. On passing westward the folds gradually dip at lower and lower angles to the eastward, till, near Airicheirie, the dip is E. 10 N. at 30°. In the intermediate areas, on the heights of Meall an Torcain and Tom Ban Mòr, the dips are 60°—45° gradually acquiring a lower angle towards the westward. Thin bands of brown biotite schist from a few inches to several feet in thickness are common all through the series, but they acquire a greater development on the line of strike, passing from Meall an Torcain over Meall Coire nan Laogh towards Carn Gorm Loch. Here a series of thicker bands some yards in width, but with intercalated bands of quartzose schists, occur. over a breadth of 300 yards. They consist of wavy bluish-black biotite schist, weathering a brownish colour. Small garnets are not uncommon. To the west of these biotite-schists bands, on the south-west slope of Meall an Torcain occur two well-marked bands containing many garnets. They cross Tom Ban Mor, and Meall Ghorm, to Meallan Ban, where they pass out of the district surveyed. The rock is a flaggy muscovite biotite schist, full of small perfect garnets, very similar to the muscovite biotite schists of Eastern Ross, but the structure is less coarse. Accompanying these bands are white pegmatites with large crystals of muscovite, and occasional garnet. A large pegmatite of this description with a breadth of 15 yards can be followed from near Craig Rainich, across Tom Ban Mòr, on to Tom Ban Beag, apparently following the strike of the schists.

Digitized by Google

Dr. Crampton. About half a mile to the east of Aultguish Inn, a series of small crushes occurs in the schists exposed in the banks of the Glascarnoch River.

Mr. Gunn. Crystalline schists of the Moine type occupy most of the area on the east side of Strathvaich, to the north of Strathvaich Lodge. They have a prevailing northerly strike, generally trending a little to the west of north. The beds are usually vertical, or dip at steep angles to the westward, but sometimes the dip is easterly. Not much folding is visible in this area, nor are there any marked bands of biotite schist.

A pink-augen gneiss or foliated granite, which is intrusive in the crystalline schists, occupies all the area between Black Water and the Strathrannoch Burn, for a distance of 2½-miles northward from Inchbae Lodge. Much of this area is covered with drift and peat, and the rock is not well exposed, except to the north of the school-house at the Black Bridge, where it forms a fine series of escarpments trending a little west of north. The foliation in this place dips eastward at a high angle, but about Luibfearn in the direction of Inchbae, the dip is considerably to the south of east, and the amount is not generally more than 30° or 40°.

The character of this rock is the same as that described in the reports for previous years,* and therefore does not require a detailed notice. The rock extends for some distance to the east of Strathrannoch, and has again been encountered by Mr. Gunn in the Kincardine districts of Ross-shire, and by Dr. Crampton in Strath Rusdale and the neighbourhood—*See infra.*

Dr. Crampton. *Strathrusdale.*—In the Alness district of Ross-shire, Dr. Crampton who was stationed in Strathrusdale, found the greater part of his area composed of various kinds of crystalline schists with associated igneous rocks. The latter consist of the augen-gneiss and hornblendite sills. The north-eastern corner of the area is occupied by an intrusion of unfoliated granite. Two very small exposures of scyelite occur near the summit of Meall nam Gabhar.

The crystalline schists occupy the greater part of the area. The prevailing type of rock is a granulitic quartzose schist. A broad band of dark muscovite biotite gneiss is the only one which has been definitely traced across the whole area. This rock contains large flakes of white and black micas and strings of felspathic and pegmatitic material. It is frequently full of garnets, which are sometimes small with good crystalline faces, but often form aggregates from the size of a pea to that of a walnut and with a crushed appearance. This band is in places more than half a mile in width without any other kind of rock. It enters the area at the northern end of Ben Tharsuinn and crossing Strathrusdale in a S.S.W. direction extends as far as the Alness River in the Boath Valley where it is cut off by a fault. The band reappears on the S.W. shore of Loch Morie, about one mile from the outlet, and forms a crag facing the loch.

* *Summary of Progress* for 1898, p. 9, and for 1900, p. 8.

Digitized by Google

It then passes over Meall Beag in a S.W. direction. The dips of this rock in the most northerly part of the band are very high and mostly in an easterly direction, but with occasional reversals to the W. As the band passes southward into Strathrusdale the dips have an E.S.E. direction at angles of 50°–60°. Further south and on the south side of the fault the dips become S.E. at angles usually about 45°. To the south and east of this band, and apparently overlying it, is a series of thin bands of a yellowish quartzite, weathering on the surface to a pure white, and alternating with bands of muscovite biotite gneiss of much the same character as the broad band described above. With these occur a thick series of flaggy granulitic quartzo-felspathic gneisses and bands of a more massive character, with a large proportion of pink felspar in strings and lenticles. Where the alternations of muscovite biotite gneiss and quartzo-felspathic rocks are more rapid there is a tendency for both members to become very flaggy in character, and to pass gradually from one kind of rock to the other through intermediate rocks called "spangle schists." These are granulitic quartzo-felspathic rocks of a very flaggy character and they contain scattered through them large flakes of muscovite which give the cleaved faces of the flags a spangled appearance. With these rocks are associated strings and lenticles of white pegmatite containing large crystals of white mica, which frequently enclose garnets. These pegmatites are sometimes of a large size and appear like dykes. The strike and direction of dip of all these schists which lie to the S.E. of the large band of muscovite-biotite-gneiss coincide in the main with the strike and dip of that band as described above. The broad belt of muscovite-biotite-gneiss on its N.W. margin is succeeded rather abruptly by granulitic quartzo-felspathic schists of the Moine type which appear to dip beneath it. Schists of this type devoid of bands of muscovite-biotite-gneiss, but enclosing some of biotite schists, occur all over the wide region to the west as far as Bad a Bhathaich and the northern end of Loch Morie. The strike and dip of these rocks follow the general direction of that of the schists to the eastward, but throughout the regions of Carn Beag and Craig Braigh ant Stratha and to the west of these elevations, the rocks are much contorted and folded, the dips being frequently to the S., S.W., and West. A thick band of bluish grey mica schist with a finely crimped structure caps Carn Beag and extends about one mile southward towards the outlet of Loch Morie. It is much interfolded at its margins with the underlying quartzose schists. Its general dip seems to be to the S.W., but there is much contortion. Along a line beginning at the junction of Allt Coire na Capuill with the Amhainn Glac ant Seilich and passing in a S.S.W. direction west of Bad a Bhathaich and thence through Meall Toll a Choin, above Kildermorie, the quartzo-felspathic schists give place to bluish-grey mica schists of the same type as those capping Carn Beag, but not so crimped and generally of a more phyllitic character. These mica schists dipping sometimes to S.E. and sometimes to

Dr. Crampton

Digitized by Google

Dr. Crampton

S. and S.W. pass gradually in a westerly direction into a bluish-grey hornfels. Rock of this type forms a zone of metamorphosed sediment, with a width of about half a mile, bounding the augen-gneiss described below. The minerals of the hornfels are usually too small to be distinguished with the naked eye. The rock as a whole has a very homogeneous appearance but distinct banding on a very small scale, evidently that of original bedding, is brought out on weathered surfaces. Near the margin of the augen-gneiss minute knots occur, and within a few yards of the junction large garnets have been developed and the rock is extremely hard and has a very baked appearance.

Dr. Flett has examined sections of the hornfels which has been produced by the augen-gneiss evidently acting as an igneous intrusion. He states that they are "finely banded hornfelses in which knots are well developed so that they may be described as Knotenschiefer. The banding is probably original bedding. Under the microscope they are fine-grained and consist of biotite, muscovite, quartz, and felspar. Small garnets spongy with enclosures are frequent. The knots consist of subradiate scales of pale mica. In one or two slides the original grains of clastic quartz are still to be traced in certain more gritty bands. Some of these hornfelses show no trace whatever of mechanical deformation subsequent to the thermal metamorphism." One of the specimens from Crag west of Kildermorie Lodge is a garnetiferous sillimanite biotite hornfels. Sillimanite in tufted needles is very abundant from the river bed west of Kildermorie Lodge. Another specimen shows garnets over $\frac{1}{4}$in. in diameter filled with enclosures of quartz, magnetite, etc. Clinochlore, green hornblende, and rutile are present. It is, therefore, evident that these rocks retained many of their clastic characters at the time of the introduction of the augen-gneiss, which in the respect of the hornfelsing has behaved as an igneous mass. In virtue of this hornfelsing they have escaped being converted into schists of the Moine type into which they pass out laterally.

The best exposures of the rocks of this metamorphosed zone are seen in the crags on both sides of the river above Kildermorie Lodge. There is also a good section in the river bed where the hornfels can be traced right up to its junction with the augen-gneiss. The junction is also exposed on the north bank of the river and at the summit of Carn Cas nan Gabhar.

Augen-gneiss, like that of Inchbae, is seen in junction with the hornfels in the river about half a mile above Kildermorie Lodge. The rock is a foliated granite in which a matrix of quartz, felspar, and black mica flows round large eyes of felspar. The line of junction passes in a N.N.E. direction up the Crag on the north bank of the stream, and the augen-gneiss has been followed to Carn Cas nan Gabhar, where it is seen near the summit of the mountain in junction with the schists. On the south bank of the river above Kildermorie Lodge the line of junction swerves to the N.W. and again crossing the river passes up the burn coming from Lochan Lice. The line

Digitized by Google

of junction again changes its direction and is continued W.S.W. so as to cross the river once more about a quarter of a mile below the bridge. The strike of the foliation where observed is N.N.E. and S.S.W. The margin is rather abrupt in the region about Kildermorie, but small tongues and veins of the rock penetrate the schists. At the summit of Carn Cas nan Gabhar the junction can only be described as an intricate network of schist and igneous rock. Inclusions of schist are frequent within the margin of the gneiss, which sends out veins sometimes foliated like the gneiss itself but often quite devoid of any foliation, into the schists all along the boundary. The smaller veins are crowded with small rounded grains of blue quartz. Dr. Crampton

Hornblendites.—Small lenticular sills of hornblendite containing garnet occur associated with the muscovite biotite schists and also with the quartzose rocks. The largest, about 30 feet across, are seen in the Craig Ard a Briarh. The margins of these lenticles are well foliated and often show ball-like masses of crushed garnet wrapped in scales of brown biotite.

Scyelite.—Two small exposures of scyelite occur in the peat 300 yards N.N.E., and 400 yards E.N.E. of the cairn of Carn Cas nan Gabhar. They appear to have a somewhat dyke-like extrusion, but their relations to the surrounding rocks are not seen. Patches of a rock of a more acid character full of hornblende crystals are seen sticking to the scyelite in the more northerly exposure.

Dr. Flett, who has examined specimens taken from the more northerly exposure, calls the rock a biotite-hornblende-peridotite or scyelite. The beautiful lustre mottling seen in the hand specimen is due to the hornblende enveloping the biotite in poikilitic fashion. There is no shearing structure, but cracks and distortion of the biotite and hornblende, due to expansion of the olivines during weathering, are very noticeable. The rock closely resembles the original scyelite of Professor Judd (*Q.J.G.S.* 1885, Vol. 41). The more acid rock sticking to the scyelite is a quartz diorite of a basic kind almost approaching a hornblendite. Green hornblende, showing good crystalline outlines and brown biotite, are associated with a peculiarly acid interstitial material consisting largely of micropegmatite.

Granite.—A pale pink granite, an extension of a larger mass to the northward, occurs on the north-east flanks of Beinn Tharsuinn and Doire Leathann. Its constituents are a pink felspar, large clear quartzes with a strong tendency to good crystalline outlines, and small flakes of a brownish biotite. The latter is almost absent in some places, especially in the numerous veins which penetrate the schists along the margins. The metamorphism produced by the granite on the schists is very slight, and apparent chiefly in the direction of a greater development of muscovite. Boulders of this granite occur in conglomerate of Old Red Sandstone age about one mile distant in the Strathrory River. These boulders had been previously noticed by the late Hugh Miller. Dr. Flett reports on an examination of a slice of

Digitized by Google

Dr. Crampton

this granite, that it is a biotite granitite containing microcline. Orthite is present as an accessory.

The population in this area is distributed along the Blackwater River in Strathrusdale, and the district of Boath. It consists of the inhabitants of about a dozen crofts, who gain a living almost entirely by sheep farming. The only cultivated lands are narrow strips on the alluvia of the Blackwater and Alness rivers, and larger patches in the neighbourhood of Boath on the mudstones of the Old Red Sandstone. The crops grown are oats, turnips, and potatoes for home consumption. Kildermorie Lodge also lies in the area surveyed, and is surrounded by a few keepers' houses.

The boulders of augen-gneiss have been used largely throughout the district for the building of houses and bridges, One boulder supplied material for two cottages, with rock to spare. It is said that the rock splits well and makes an excellent building-stone. The method used for splitting the stone is called "pegging and feathering." Over the greater part of the district the land is not fit for cultivation.

Mr. Gunn.

Kincardine district.—The principal rocks which are found in the Kincardine district are crystalline schists, augen-gneiss, and granite.

The crystalline schists of the Kincardine district are mainly of the siliceous Moine type. They are, in general, flaggy, with a fair amount of mica, especially on the bedding planes, but in not a few places they are thick bedded and very quartzose, and the mica is sparsely developed; while in some places the rock is massive, and the foliation obscure. The dip of the foliation is generally southward, and at high angles along the Carron River. The same dip is continued a good way up Allt Downie, but is less in amount, and the beds are repeated by a series of flattened folds. Over the large part of the Kincardine area the foliation dip is generally directed between E.S.E. and S.S.E., so that the average strike of the rocks may be said to be north-east. Near the northern edge of the main mass of granite, however, the strike tends to become parallel to the boundary line of the granite, or W.N.W. A marked example of this kind may be examined up Wester Fearn Burn. About Conà Chreag nan Clach there is a considerable area where the rocks are sharply plicated in a north and south direction.

Two broad bands of muscovite biotite-gneiss have been traced in the neighbourhood of Easter Fearn, and under Struie Hill. They are separated by a band of siliceous schist, which is half a mile wide opposite Struie, but which apparently becomes very narrow near Corriefearn, so that it seems probable one band is a folded repetition of the other. One of these forms Dun Criech, on the north side of the Dornoch Firth. There is no doubt that these bands are a continuation of one which has been traced by Dr. Crampton, in a north-easterly direction from Strathglass, across Strath Rusdale, till it is truncated by the granite north of Beinn Tharsuinn.

Digitized by Google

Thin bands of hornblende-schist occur on the shore, and in the railway cutting two miles east of Easter Fearn, and some small masses of epidiorite and of hornblende rock are found in a few places. Mr. Gunn.

Augen-Gneiss or Foliated Granite.—The north-eastern extremity of the augen-gneiss or Inchbae rock, curves round from Carn Salach, and Carn Bhren, by Carn an Liath-bhaid to Meall na Cuachaige, but only a part of the boundary has been mapped. It is evidently of the nature of an intrusive granite sill which has been folded and foliated with the schists. In this district it appears to be everywhere in contact with rock which was once an argillaceous sediment, and which has undergone a great amount of alteration, having been converted in great measure into a hornfels with a development of contact minerals as andalusite, &c.

The width of this mass of igneous rock where it is known at either end (Inchbae or Carn Bhren), is from two to three miles, and it is probable that there is a continuous outcrop of it forming an isoclinal fold, stretching for about seventeen miles from its S.W. extremity near Beinn nan Cabag to Carn an Liath-bhaid at its N.E. boundary. This direction appears roughly to coincide with the general strike of the schists, into which it was intruded, and is in striking contrast with that of the greatest length of the mass of unfoliated granite which is found to the east of it, on the south side of the Dornoch Firth near Kincardine. The latter trends to the N.N.W., and cuts markedly across a thick band of muscovite biotite gneiss which strikes N.E.

Granite.—The mass of pink or red unfoliated granite stretches in a N.N.W. direction for a distance of six miles, from the Strathrory River beyond the Wester Fearn Burn, but the central portion of this area is not yet completed. Its average width is more than two miles. To the north of the main granite area small bosses and veins of granite occur in several places. They are particularly numerous along the shore south of Ardgay, and in Church Hill. This reddish biotite granite is in general moderately coarse, and the quartz which it contains often tends to become idiomorphic. The biotite is sometimes but sparingly developed. In places *e.g.* in the main part of Easter Fearn Burn, the granite is much decomposed, and very soft. There is a fine section of the rock in the gorge of the Wester Fearn Burn, where the granite is harder, and where it includes two broad bands of siliceous-schist.

As fragments of this granite are found in the lower Old Red conglomerate, it is clear that its intrusion was prior to the Old Red Sandstone period.

Two dykes of mica-trap running in an east-south-east direction pierce the schists in Allt na-h-Eiteig, and in Wester Fearn Burn dykes of a somewhat similar character penetrate the granite.

OLD RED SANDSTONE.

Ross-shire, Achilty.—The mass of coarse basal breccia that forms the summit and eastern face of Torr Achilty lies between Mr. Hinxman

Digitized by Google

Mr. Hinxman

two faults, both with a down-throw to the east. These faults have been traced through the schists on the south side of the Conon, and after crossing that river they run in a N.N.E. direction, until they probably converge beneath the alluvial plain which lies between the base of Torr Achilty and the village of Contin. The most easterly of these faults throws down a pebbly conglomerate with intercalated beds of grey shale against the basal breccia on the west, which contains angular blocks of schist three and four feet in length. The breccia and the intercalated series on either side dip in opposite directions towards the fault. By the other fault the breccia is brought against the Highland schists half a mile further to the west. The down-throw of this fault on the southern face of the hill is evidently small, but on the north side the breccia lies in a deep hollow against a steep cliff of schist. Between the two faults the Old Red Sandstone rests unconformably upon nearly vertical beds of reddened and shattered siliceous schist.

Inverness-shire.—The western boundary of the Moray Firth Old Red Sandstone Basin has been traced southwards and eastwards from the Beauly river at Eskadale to the head of Glen Convinth. The base of the formation is everywhere a coarse conglomerate-breccia—a tumultuous aggregate of rounded and subangular fragments of all sizes, from small pebbles up to blocks three and four feet in length, set in a sandy matrix.

The included stones are almost entirely derived from the local crystalline schists, but there are also a few rounded boulders of unfoliated biotite granite and pegmatite, one of the latter measuring six feet in diameter.

A short distance in from the margin, beds of shaly greenish and red sandstone are intercalated with the conglomerate, but these do not exceed a few feet in thickness.

Mr. Gunn.

Strath Vaich Forest.—The Old Red Sandstone occupies a strip of ground more than a mile in width, on the east side of Strath Vaich, between the Moine schists and the augen gneiss, and it runs a long way up the main stream of Strath Rannoch. An outlier of this formation also caps Meall-a-Ghrianain (2531 feet). The Old Red strata rest unconformably on both the older crystalline rocks, and its basal breccia is largely made up either of fragments of augen gneiss or of schist, according to the character of the rock on which it reposes. It appears that the surface of the crystalline rocks immediately prior to the deposition of the Old Red Sandstone must have been very irregular, and somewhat comparable to that of the Lewisian gneiss when the Torridonian formation was formed.

The Old Red Sandstone consists of breccias and conglomerates, sandstones, and mudstones. No regular succession can be made out satisfactorily as the ground is much obscured by drift and peat, and there are probably faults which are not visible. In the burns east of Creag Bhreac Mhor there are sections in purplish red mudstones, in which occur green streaks and also sandy bands. These latter show that the rock dips to the south-east at

Digitized by Google

comparatively low angles of 15° to 20°, while the most prominent planes, those of cleavage, dip to the N.N.W. at angles of 50° to 60°. Mr. Gunn.

The outlier which forms Meall-a-Ghrianain is remarkable. As far as can be made out it consists almost entirely of blocks of augen-gneiss in a somewhat sandy matrix. The blocks are of large size, many being as much as ten feet in length, and there are some still larger. On the south-east side of the hill blocks of schist were also noticed in the conglomerate. There is no satisfactory outcrop on the hill top, which is covered with loose blocks of augen-gneiss apparently derived from disintegration of the breccia. The best section of the mass is on the west side of the hill about 550 yards W.N.W. of the ordnance station, and the cliffs there expose more than a hundred feet of the conglomerate. In one place there is an intercalated band of reddish sandstone one foot in thickness which has a gentle southerly dip, and this is probably the dip of the whole outlier, for the base of the mass must be 300 or 400 feet higher at the north than at the south end.

The large blocks of augen-gneiss so abundantly scattered over the area between Strathvaich and the Glascarnoch Valley were probably derived from this outlier, having been distributed during the glacial period.

It is difficult to account for the composition of this mass, as no augen-gneiss is known to occur *in situ* anywhere near it, and the blocks of which the basal portion is composed appear everywhere to repose on the ordinary siliceous Moine schists of the district. It is quite possible, however, that there is a core of augen gneiss *in situ* near the summit of the hill, concealed under the *débris* of the conglomerate.

The size of the blocks in this breccia is far above what usually occurs in the basal conglomerate of the Old Red Sandstone, in which the stones seldom exceed the length of two feet, and most of them are below that size. An exception to this, however, occurs in the basal breccia near its unconformable junction with the schist in the stream nearly a mile east of the summit of Meall-a-Ghrianain, where one of the blocks occurring in the breccia is 18 feet in length.

Reference was made to these areas of Old Red Sandstone in the Annual Report for the year 1896, p. 53, but they had not then been surveyed. It is known that rocks of this formation extend for a considerable distance to the east of Strath Rannoch but this part is not completed.

Three small outcrops of conglomerate which are found in the banks of the Strathvaich River between Lubriach and the Black Bridge were mapped by Dr. Crampton. Two of them are connected with the Old Red Conglomerate to the eastward, while the third which is the nearest to the Black Bridge is probably a smaller outlier. They consist entirely of schist pebbles in a red matrix. Dr. Crampton

Alness District.—A junction of the schists and Old Red Sandstone is to be seen in the Tollie burn one and a quarter mile above the bridge at Ardross gates. The Old Red Sandstone

Digitized by Google

Dr. Crampton. distinctly faulted against the schists shows here a thin conglomerate which can hardly be separated from the brecciated schist occurring in the fault. The conglomerate is succeeded by red sandstones and thin purple and green mudstones all dipping to the S.W. The mudstones can be followed in the burn as far as Bractollie. The direction of the fault is N. 35 E.—S. 35 W.

The other area in which the Old Red Sandstone enters into the ground surveyed is in the Boath district. Here the line of junction of the Old Red Sandstone and the schists is partly a fault and partly also an unconformable one. The N.E. face of Cnoc Liath Fad down to the 1,000 feet line consists of a conglomerate of schist fragments and pebbles in a reddish matrix. On the south slope of the hill the conglomerate is in unconformable junction with the schists which at the W. end of the hill are in place as high as the 1,750 feet line. The line of junction has an abrupt descent at the N.W. end of the hill and crosses the low lying ground immediately south of Craig na Glaic and Boathvie towards the junction of the rivers near Strone. The basal conglomerate of Cnoc Liath Fad gives way to a series of purple and bluish-black mudstones in the low-lying ground about Glack, but the relation of the two sets of rocks to each other is obscure. There is however a thin basal conglomerate south of the Craig na Glaic. The whole of the low-lying area of Boath consists of purplish mudstones with occasional thin sandstone, which are well seen in the burn sections, but elsewhere they are largely covered by drift. These mudstones are limited in their northward extension by a fault lying a little to the S. of the Alness river, which brings them in contact with the schists. A second fault seen in the burn above Ballone brings the series against the schist to the south. Cnoc Liath nah-Acain forms the northern extremity of a ridge of conglomerate extending from Meall an Tuirc in Strathglass. The conglomerate is faulted against the schists to the W. by the great boundary fault the extension of which to the N.E. in the Boath district is obscured by drift. The dark bluish mudstones immediately to the W. of Glack show pale blue phosphatic marks which suggest fish remains, though nothing more definite has been observed.

TERTIARY.

Mr. Clough. *Inverguseran.*—Tertiary Dykes are somewhat numerous in the south part of the Inverguseran district. Most of them are basaltic and tend N.W. or N.N.W.

GLACIAL PHENOMENA.

Glenelg District.—Glacial striæ cross the Glenelg-Loch Duich watershed in Bealach Ratagain in the pass a mile N.W. of Sgurr Mhic Bharraich and in other places, one of them more than 2,500 feet high, further S. Granite boulders occur on the N.E. side of Bealachachasain house, and must have been carried over the watershed in a S.W. direction. Granite boulders have also

Digitized by Google

been carried S.W. right across the main area of diorite and augite syenite on to the Lewisian gneiss rocks near Strathchomair. This probably indicates that the pressure of ice coming over the watershed from the N.E. and E. was at one time so great that the ice from the E. slopes of Ben Sgriol and Beinn a' Chapuill was unable to advance eastwards. Mr. Clough.

The floors and sides of the glens are to a large extent covered with small morainic mounds, but deposits of stiff grey boulder clay also occur. Excellent exposures of this clay are found near the heads of Ghleann Aoidhdailean and Bealach a' Chasain.

A little E. of Strathchomair, and on the low watershed between the Gleann Beag and Glen More of Glenelg, there is an extensive and thick deposit of fine sand and gravel. The materials composing the deposit are exposed in a good section, where they are quite free from large boulders, though such boulders occur in abundance scattered over the top and on the sides of the outcrop. The sand must have been deposited in still water, and probably in a loch, though it is difficult to see how a loch can have existed in this locality unless some of the banks were formed by ice.

A little N. of, and about 40 feet higher than, the sharp bend in the Gleann Beag burn are remains of an old gravel terrace, the top of which is nearly horizontal though the burn below has a rapid fall. The terrace is very near the deposit mentioned in the preceding paragraph and possibly of the same age.

On the E. side of the burn, about a mile S. of Bealachachasin house, is a series of seven or eight short terraces, the N. and S. parts of which end abruptly against moraine covered slopes of about the same elevation. Perhaps these terraces were formed while most of the glen bottom and the sides were still covered with ice.

Fannich Forest.—In the Fannich Forest, well-marked groups of moraines were found by Dr. Horne, in the valleys draining into the Cabuie river, and at the head of Allt a Chleibh, and Mr. Gunn reports that beautifully-formed moraines, which often trend nearly east and west are abundant to the east of Loch Li. Some of these, which are several hundred yards in length, are extremely narrow, run in almost perfectly straight lines, and have steep edges on their northern sides. Dr. Horne and Mr. Gunn.

Inverness-shire and Ross-shire.—The glacial drift in the higher parts of Strathglass and its tributary Glens, may all be referred to the later valley glaciation. It is only in the low ground valleys of Kiltarlity and on the northern slopes of Glen Urquhart that any true boulder-clay has been observed, in some cases underlying later morainic deposits. Mr. Hinxman.

The glacial striæ and the dispersion of carried blocks in this region point to a general easterly movement of the ice outwards from the high mountainous region in the west.

Evidences of the later phases of the valley glaciation are abundant among the mountains of the Inverlael Forest, whose glens and corries afford splendid examples of lateral and terminal moraines.

Digitized by Google

Mr. Gunn and Dr. Crampton

Ross-shire.—The finest set of moraines occurs on the north side of the River Lael, at An Cnapach (The Knolls) to the south of Lochan a' Cnapaich. The water of the loch disappears under the loose material of the more conspicuous moraines and comes out again to the south in several fine springs. A well-marked moraine 500 yards in length, which trends north-east, occurs on the water-shed north of the head of the River Lael, at a height of 2750 ft. above the sea, and there is a pretty series of moraines to the N.E. of this in the valley west of Loch Tuath. There is very little glacial drift in Dr. Crampton's part of the Inverlael Forest, and what occurs is of a loose character and full of blocks and fragments of the rocks in the immediate neighbourhood.

Mr. Gunn.

As will have been gathered from the description of Strathvaich Forest, much of the area is covered with glacial drift, but there are few good sections of it. The older boulder clay, or till, apparently overspreads a large part of the augen-gneiss area, assuming in Druim Buidhe the form of a drumlin trending south-east. Good examples of linear moraines are found in the valley east of Meall a Ghrianain, but perhaps the finest, which is nearly half-a-mile in length, occurs on the east side of a small stream to the north of Druim Buidhe. Large blocks of augen-gneiss from the conglomerate of Meall a Ghrianain, several as much as twelve feet long, have been distributed to the eastward, southward, and westward of the hill and they must have been carried, at one time, south-westward across the valley of Strath-vaich. This was probably when the ice had attained its maximum thickness, and the ice-shed was considerably to the east of the present main water-shed of the north of Scotland. It seems probable also that those found scattered on the Loch Broom side of the present water-shed (see *Report of Geol. Survey for* 1896, p. 18) may have also been derived from the same outlier.

Dr. Crampton

Strathvaich.—Dr. Crampton, in his area, finds that the drift is thickest in the lower part of Strathvaich, where it has been cut through by the river and terraced. It consists of a loose earthy accumulation of large and small boulders of schist and augen-gneiss. The western slopes of Strathvaich are covered with moraines full of similar boulders. A fine series of Kames occurs immediately south of Strathvaich Lodge. The most noticeable of these has a serpentine form, and is 600 yards in length. Augen-gneiss boulders are plentiful on the heights south of Tom Bàn Mòr. One on Sron Ghorm measures 18′ × 8′ × 5′. Ice striæ with S.E.–N.W. direction occur on the summits of Meall an Torcain and Sron Ghorm. Striæ near the base of Meall an Torcain have a direction E.S.E.–W.N.W. A few blocks of conglomerate are scattered over the summit of Meall Coire nan Laogh.

Strathrusdale.—Glacial deposits of great thickness occur in the valley to the east of Cnoc Liath nah-Acain leading from Boath to the junction of the rivers in Glen Glass. Sections of this deposit 30 feet in depth occur in the Allt na Seasgach, without rock being seen in the river bed. This drift has much the appearance of till, containing large, much-worn boulders of augen-gneiss and schist, and is full of smaller *débris* of schist and mudstone. It is quite

Digitized by Google

loose and unconsolidated and appears to pass gradually into the thinner drift of the valleys to the westward. The low-lying ground to the east of Doire Leathann in the basin of the Strathrory river shows the same unconsolidated earthy drift of great thickness. Here, however, the predominant constituent is *débris* of the pink unfoliated granite which forms the ground to the N. and W. Small fragments of the Cambrian Pipe-rock occur in the drift of this area. One of the most noticeable features of the country is the quantity of immense boulders of augen-gneiss which occur everywhere up to the highest altitudes. Boulders of 10 feet diameter occur on the top of Beinn Tharsuinn. The largest boulder measured lies in the plantation to the N. of Bracantra in Strathrusdale. It is 61 feet in girth and 15 feet high. The augen-gneiss, however, occurs in places only three miles distant from this boulder. Fine examples of *roches moutonnées* are seen at the base of Cnoc a' Mhadaidh and on the opposite hill, Am Mam, and the striæ found upon them point E. 30 S., and their long axes are arranged in the same direction. A few boulders of Scyelite occur near the large augen-gneiss boulder. These have apparently been derived from the exposures of Scyelite on Carn Cas nan Gabhar, and lie in an E. 30 S. direction from the parent rock. Small morainic accumulations occur along the slopes in Strathrusdale. Dr. Crampton

Kincardine District.—In the Kincardine district there are extensive deposits of glacial drift, much of it of a morainic character and loose in texture. It appears to be thickest in the neighbourhood of the Easter Fearn Burn, east of Corriefearn. The main glaciation, as shown by striæ on the solid rock, was from the W.N.W., and conspicuous hills in the low ground, as Church Hill and Cnoc Bad-a-Bhacaidh, have long and thick tails of drift on their lee or E.S.E. sides. In the lower part of the Carron Valley and elsewhere are many mounds of sand and gravel or kaims. A pretty set of such mounds occurs to the south-west of Blar Garvary, near Abhuinn a' Choire Bhuig, at a height of nearly 900 feet above the sea. Well formed moraines are very conspicuous to the west of Gradal on the Kincardine Burn. Many large boulders of the augen-gneiss occur along the Kincardine shore, and they are particularly numerous down the Wester and Easter Fearn Burns. Mr. Gunn.

POST GLACIAL.

Both the 25-feet and the 100-feet raised beaches are well developed near Inverguseran, and between that place and Airor. The 100-feet beach extends up Glean Ghuserein for two miles. Mr. Clough and Mr. Gunn

The Dornoch Frith is very shallow, and extensive modern deposits of mud are laid bare at low tides. Raised beaches are not conspicuous, except at the mouths of the principal streams. The 25-feet and 50-feet beaches can generally be traced on both sides of the Firth, but the 100-feet beach appears to be generally absent.

Digitized by Google

2. West Highland District.—Knapdale, Lorne and northwards to Loch Eil, Skye.

Mr. B. N. Peach, F.R.S., District Geologist.

Mr. C. T. Clough,
Mr. J. S. G. Wilson,
Mr. H. Kynaston,
Mr. A. Harker,
Mr. C. B. Wedd,
Mr. H. B. Muff,
} Geologists.

Work was carried on during the season in two separate regions. The chief district is on the mainland in the counties of Inverness and Argyle, and stretches from Loch Shiel in the north to the Crinan Canal on the south. The one-inch maps in which this area is comprised are 36, 37, 44, 45, 53, 54, 62. The other district is in the Islands of Skye and Soay in Sheets 70 and 71.

The principal Geological Formations and rock groups dealt with are:—Highland Metamorphic rocks, and associated gneisses; Torridon Sandstone; Metamorphosed Cambrian Dolomites; Lower Old Red Sandstone and associated volcanic and intrusive igneous rocks; Triassic, Jurassic and Cretaceous strata; Tertiary volcanic and intrusive igneous rocks; Glacial deposits; Raised Beaches, Peat, and Alluvium.

Highland Metamorphic Rocks.

The region in which work was carried on in the Highland Metamorphic schists, under the supervision of Mr. B. N. Peach as District Geologist, stretches roughly along the west coast from Loch Shiel in the north to the Crinan Canal in the south. For convenience of description the region may be provisionally divided into two, viz.:—(*a*) one north of the Great Glen and the Linnhe Loch, and (*b*) one south of that line.

(*a*). *Region north of the Great Glen and the Linnhe Loch.*

Mr. Wilson.

Mr. Wilson is the only geologist who did field work in this district. The rocks in this region are chiefly schists of Moine type, and the muscovite-biotite gneiss. Though here described first in order it is not intended to imply that they are older than the schistose rocks south of the Great Glen. It has been shown in many former reports and *Summaries of Progress* that rocks of identical character with these occur over wide areas of country south of this line.

From his station at Corpach, Mr. Wilson continued fieldwork in Sheets 53 and 62, and mapped an area of 37 square miles, extending from a line drawn from the head of Loch Sheil south-west as far as the middle of Glen Scaddle, north-westwards to within a short distance of the upper end of Loch Shiel and the heads of Cona Glen and Glen Scaddle.

Digitized by Google

Mr. Wilson.

The whole of this district is mountainous, and the different kinds of rock produce a poor and very inferior soil. The flagstones weather so slowly that any soil produced by their denudation is at once removed by the various atmospheric denuding agents.

The denudation of the muscovite-biotite gneiss to the west of the flagstones has produced very rugged and rough hill masses, which are either bare rock or else partially covered with a short, bright green herbage. This is due to the lodgement between the rock ledges and on the shelves of small and thin patches of light sandy soil derived from the disintegration of the gneiss. This soil is also scattered over the surface of the moraine slopes which cover the lower portions of these hills.

On both sides of Glen Scaddle the weathering of the foliated epidiorite has resulted in hills with long grassy slopes and rock ridges which culminate in sharp peaks. As this basic rock is much softer than the surrounding flagstones it has produced a considerable quantity of soil which is scatted over the lower hill slopes. This soil contains a small percentage of alkalies, etc., and as a natural result Glen Scaddle has the best grazing ground in this part of Argyleshire.

The larger portion of the grazing ground in North Ardgour is confined to the gravelly and sandy moraines, which are found in every valley and hillside. As the materials which compose these moraines are chiefly derived from the local rocks the grazing is only of a moderate quality.

Between the head of Loch Eil and Creggan there is a considerable belt of flat ground covered with deposits belonging to the 50-feet beach. When not covered by peat these haughs are fair grazing ground. The arable land is confined almost entirely to this raised beach on both sides of Loch Eil and the west side of Loch Linnhe. The crops grown by the crofters and on the farm lands include potatoes, oats, hay, with a few acres of turnips. With the exception of the hill pastures belonging to the various crofting townships the only grazing lands are confined to the lower portion of Glen Scaddle. All the remaining portion of North Ardgour has now been cleared of sheep and cattle and converted into deer forest.

To the south of the Creggag and Garvan, and in Glens Stronchreggan, Cona, and Scaddle, there are still to be found considerable remains of the old Caledonian Forest. Up to the beginning of the last century this part of Ardgour was covered with a forest growth, which was extensively cut down by the Bunawe Iron Co. and converted into charcoal, and shipped from Inverscaddle Bay to the iron furnace on Loch Etive. Large tracts of this country, which at present are barren moor, could be profitably planted up to a height of 1,000 feet.

There are no quarries or rock suitable for building purposes in this district.

The population is a scattered one, being confined chiefly to the crofting townships on Loch Eil and Loch Linnhe, and around Glen Finnan Railway Station. The stream water supply is good and abundant all over this district, but in no single instance has the abundant water power been utilised for industrial purposes.

Digitized by Google

Mr. Wilson.

The solid rocks which enter into the area are crystalline schists of Moine type, muscovite-biotite gneiss which form the "rocks of the country," and various igneous intrusions, some of which have been rendered schistose and metamorphosed, while others have retained their igneous structures, and are probably of later date than the metamorphism of the region.

The Moine schists or granulitic quartz schists with more or less felspar and mica form the south-eastern half of the area, and resemble the rocks described in former *Summaries of Progress* of which they are a continuation.*

The muscovite-biotite gneiss is a coarsely crystalline rock with muscovite and biotite in large flakes, and with quartz and felspar, which may be scattered either more or less regularly throughout, or may be arranged in layers, knots, and lenticles of varying size. The rock in places is flaggy and alternates with layers of granulitic quartz schist of Moine type, while in other places it becomes massive and coarse and assumes the appearance of a foliated igneous rock. In certain parts of the present area it is much traversed with knots, strings, and veins of quartzo-felspathic material, sometimes carrying muscovite or biotite, or even both micas, and the crystalline texture is often coarse, which in further descriptions will be named "pegmatites."

Rocks of the type of the muscovite-biotite gneiss, as above described, occupy nearly all the rest of the area surveyed; but this area is only the edge of a very wide belt of such rocks. A traverse was made along the line of the newly-constructed Mallaig railway while the rock cuttings were still fresh, and the muscovite-biotite gneiss belt was found to extend as far to the west as Kinlochailort station, the limit of the traverse, a distance of thirteen miles from the southern boundary of the belt. The direction of this section of railway is almost at right angles to the strike of the schists.

Igneous Rocks Associated with the Moine Schists and Muscovite-Biotite Gneiss.

Foliated Igneous Rocks.—Between Glen Scaddle and Cona Glen Mr. Wilson mapped the extension of the Glen Scaddle intrusive igneous complex and two small outlying masses within the area of the Moine schists. The rocks consist of foliated epidiorite with its marginal zone of granulitic gneiss like that described in former *Summaries*.† He also met with diorite and grey basic dykes of the same type as those described in the *Summary* for 1900.‡

Amphibolites and hornblende schists occur as sills and dykes in the muscovite-biotite gneiss.

---

* *Summary of Progress*, 1897, p. 65; *Ibid*, 1898, p. 40.

† *Summary of Progress* for 1898, pp. 40, 41; *Ibid*, 1890, pp. 45, 46.

‡ *Summary of Progress* for 1900, pp. 45, 46.

Digitized by Google

Later Igneous Dykes.—Between Glen Scaddle and Loch Eil, Mr. Wilson. Mr. Wilson dealt with unfoliated granite dykes cutting and altering the Moine schist of the types mentioned in previous *Summaries.**

This year, dykes of a type of rock new to Scotland, which Dr. Flett describes as "Malchite," probably connected with the later granites of the region, were discovered in the railway cuttings near the head of Loch Eil. The relation of these to the schist and foliated igneous rocks as seen in the railway cuttings is described in the sequel.

Dr. Flett adds the following summary of their characters:— Dr. Flett. "Certain of the dykes in Glen Finnan are Malchites, *i.e.*, fine grained grey dioritic dyke rocks, consisting of hornblende (green, turbid) and biotite. They include rocks which correspond exactly to the typical Malchites of the Odenwald as well as others which differ from these in several important respects."

A few dolerite and basalt dykes of the ordinary type of Mr. Wilson. Tertiary age, and with a north-west trend, were met with throughout the area.

Sections exposed in Railway Cuttings east of Glen Finnan Station.—Between Glen Finnan station and Craigag (two miles) the newly-constructed Mallaig railway passes through a series of rock cuttings which afford excellent sections of the muscovite-biotite gneiss and its relations to the various igneous intrusions and pegmatites by which it is traversed. In these cuttings there is a considerable variation in the character of the gneiss. At the station the beds are very flaggy and micaceous, and contain a much larger percentage of muscovite than biotite, and are identical with the spangle-schist of the west of Ross-shire.† To the east of the station the beds become more flaggy and quartzose, being folded on a small scale on more or less vertical axes. Opposite the Roman Catholic chapel they contain several thin bands of zoisite-schist with wine-coloured garnets. In the cutting which forms the west approach to the viaduct across the Glen Finnan valley the rock is highly micaceous (chiefly biotite), and is intersected by numerous slip faults and small veins filled with quartz. Here the planes of foliation are often slickensided with chlorite, and the presence of chlorite appears to be entirely confined to the immediate vicinity of certain amphibolite masses and dykes which are associated with the schists at this point. On the eastern side of the viaduct the character of the gneiss changes, and for some distance it is a coarse massive banded grey and pink gneiss very similar to that of the eastern edge of the belt between Glen Scaddle and Cona Glen. On the west side of the county march and above the public road in Glen Callop, the rock is a coarse grey contorted muscovite-biotite gneiss chiefly composed of felspar with muscovite. Throughout the gneiss there are small detached strings and masses of pegmatite accompanied by thin

---

* *Summary of Progress*, 1897, pp. 65, 66.

† *Summary of Progress*, 1897, p. 56.

Digitized by Google

Mr. Wilson. irregular veins and masses of quartz. Iron pyrites is disseminated through the rock. On the east side of the county march several hard granulitic bands of quartzite are associated with the gneiss. Between the Craigag Lodge and the public road the muscovite-biotite gneiss is very similar in character to that portion on the west side of the viaduct, and has a large percentage of micaceous bands.

In the railway section already described the gneiss is intersected by a large number of dykes, sills, and masses of amphibolite, which never attain any great thickness. They are all foliated and appear to have been intruded into the muscovite-biotite gneiss prior to foliation. So entirely reconstructed are these igneous intrusions that it is now a matter of conjecture whether they were originally diorites, diabases, or gabbros. Many of these intrusions contain garnets which become larger and more numerous towards their edges, accompanied at the same time by a large increase of biotite. So characteristic is this increase of biotite that many of the smaller dykes are now entirely converted into a biotite-schist. The rock on both sides of the cutting at Craigag is intersected by several of these dykes, and one microscopically examined by Dr. Flett (9684), is described by him as a normal biotite-hornblende schist.

All these amphibolites are more or less cut by pegmatite veins, but it is a remarkable fact, that as these pegmatites approach an amphibolite mass or dyke, they sometimes disappear or else become very much attenuated where they traverse the amphibolite intrusions. Another interesting fact observed is, that when a muscovite-pegmatite vein comes close to or intersects one of these amphibolites, biotite becomes the chief mica in the pegmatite for a short distance on both sides of the amphibolites.

In a cutting on the east side of the county march several foliated amphibolite dykes send branches along the planes of foliation of the gneiss, which appear to coincide with the original bedding planes of the sediments from which the schist is derived.

In this section the muscovite biotite gneiss is intersected by numerous pegmatites which vary in size from less than 1 inch up to 10 and 15 feet in breadth. These intersect the gneiss and amphibolites, and in some cases a few of them traverse thin malchite dykes in every direction. The large pegmatites to the west have a general direction of N.E. and S.W. As a rule they are unfoliated, and appear to have been introduced after the foliation of the gneiss. An exception has been noticed in one of the large pegmatites in the second cutting on the east side of the viaduct, where the vein has a rude foliation continuous in direction with that of the gneiss. These pegmatites are largely composed of felspar with quartz and muscovite mica (sometimes replaced by biotite) scattered through the felspathic base. On the east of the viaduct the small streaks and lenticles are all more or less parallel to the foliation of the gneiss, and in many cases, are cut by the larger pegmatites that cross the foliation planes. This seems to indicate that the pegmatites are of

Digitized by Google

different ages. The dyke-like pegmatites frequently cut one another, which shows that there were different periods of shattering and fissuring of the gneiss prior to their formation. The walls of these large pegmatites are clearly and sharply defined from the foliated gneiss, and the crystals of the different component minerals are often smaller next to the walls than in the rest of the vein. Mr. Wilson.

Malchite dykes traverse the muscovite biotite gneiss, amphibolite dykes and pegmatites. They are composed of a grey fine-grained holocrystalline rock, finest in grain next to the well-defined margins of the dykes. The breadth of these dykes varies from six inches up to six feet, and many of the smaller ones are slightly foliated. These are sometimes intersected by a few thin strings of pegmatite, which indicate that some of these "Malchites" were intruded towards the close of the period of the production of the pegmatites. In the second long cutting, to the east of the Glen Finnan Viaduct, there are five of the largest Malchite dykes between Glen Finnan Station and Craigag. In this section there are also several pegmatites measuring up to fifteen feet in breadth. These are cut at several points by Malchite dykes, but in no single instance was pegmatite observed to enter into them.

Region South of the Great Glen and the Linnhe Loch.

In addition to the tract already described, Mr. Wilson also surveyed a small area in Glen Nevis to the south of the Linnhe Loch. In continuation of his former work he traced the eastern boundary of the granite of Mullach Nan Coirean (*Summary of Progress* for 1899, p. 42), and the northern limit of the quartzite which forms the upper portions of Stob Ban and Sgor a Mhaim has also been mapped. This rock is a massive white quartzite with felspar. On the west side of Stob Ban, viewed from the east, it is seen to be folded twice on itself in a vertical distance of about 1,200 feet, the axial planes of the folds being nearly horizontal.

The biotite-schists (*Summary of Progress* for 1898, p. 47) which lie between the edge of the granite and the foot of the steep cone of Stob Ban are all contorted and folded more or less vertically. The quartzite dipping to S. and S.E. with an average angle of 35° seems to rest unconformably upon them. Several outliers of quartzite cap the north-west ridge of Stob Ban above Polldubh.

Loch Awe District.—With the view of finishing the survey of Sheet 45, Mr. Kynaston visited some of the islands near the head of Loch Awe, with the following result:— Mr. Kynaston

In completion of the Loch Awe area, Mr. Kynaston mapped the Island of Innischonian, near the head of Loch Awe, from Dalmally, and the small islands near Kilchurn Castle. The former consists of indurated black schists, with strong ribs of quartzite, and an occasional calcareous band. The schists are cut by a sill of hornblende porphyrite, and some small dykes of lamprophyre

Digitized by Google

Mr. Kynaston. The smaller islands, near Kilchurn Castle, show the greenish phyllites and slaty beds of the Ardrishaig type, traversed by small sills of epidiorite.

Inliers in the Lorne district.—While mapping the Lower Old Red Volcanic plateau in the south-west corner of Sheet 45, several small inliers of crystalline-schists were observed by Mr. Kynaston and Mr. Peach. Of the areas surveyed by Mr. Kynaston, he reports:—

"In the area to the west and south-west of Loch Scamadale, inliers of the older rocks amongst the Lorne andesites, indicate the presence of pale grey and silvery phyllites of the Ardrishaig type. Again, two miles south-east of the head of Loch Scamadale, another inlier occurs, consisting of black slates with calcareous bands overlain by a coarse felspathic schistose grit or quartzite, of the 'Loch Awe' type, and intrusions of a coarse type of epidiorite, rich in felspar."

Mr. Peach. Extending north-eastward from Kilbride, about five miles south-east of Oban, there is an area, about a mile long and a few hundred yards in breadth, occupied by silvery grey phyllites, black-schists, and limestone, surrounded by the Lorne andesites. The limestone bands, which are thin, dark, crystalline and micaceous, are repeated by innumerable small isoclinal folds, the axial planes of which dip towards the S.S.E. The rocks are evidently the continuation of the limestone, the black-schist, and probably a small portion of the underlying phyllitic group met with in the Loch Awe region, the "Loch Awe group" of Mr. Hill.

Mr. Muff. *Lismore and adjacent Islands.*—In order to complete Sheet 45, Mr. Muff mapped the north end of the Island of Lismore, and some of the surrounding islands and skerries, and has supplied the following report on the crystalline-schists.

By far the largest part of the north end of Lismore is composed of a dark blue limestone, which is sometimes argillaceous. The limestone is finely crystalline, and contains scattered cubes of pyrites. The argillaceous portions exhibit some sericitic mica on the bedding planes, and often alternate in thin beds with purer limestone. The limestone is thrown into folds of no great amplitude, whose axes run N.E., S.W., and very nearly parallel to the south-east coast. The folds, though commonly vertical, may be inclined to the N.W. or to the S.E., and their axes may pitch to the N.E. or to the S.W. The limbs of the folds are commonly rippled by smaller folds. In spite of this folding and crumpling, the limestone must have a considerable thickness.

The black-schist, with vertical planes of schistosity on which sericitic mica is developed, crops out chiefly on the west side of the island. It extends along the shore beneath the limestone, and runs up into the cliff in folds. Its position on the coast is often marked by an indentation of the shore line from which a depression runs inland, but in more than one case, the limestone is seen to arch over the slates, showing that the latter rock underlies the limestone. The junction between the slates and limestone is clear and well marked.

Digitized by Google

On Sliabh nam Ban-fionn, one mile W.S.W. of Port Ramsay, a breccia of considerable thickness rests on the limestone. It consists of angular and sub-angular limestone fragments, varying in size from small grains to blocks a foot or more across, lying in all positions in a limestone matrix. Some of these blocks are composed of contorted limestone, the folding of which appears to be anterior to the inclusion of the blocks in the breccia. A few pieces of black-schist occur here and there amongst the limestone fragments. On the shore, the breccia passes unconformably from the limestone on to the black-schist. The section is obscured somewhat by the intrusion of an igneous rock, referred to below, which has metamorphosed the rocks, and injected irregular veins into them in all directions. As to the age of the breccia, it is certainly of later date than the limestone and black-schist and it is cut by Tertiary basalt dykes and metamorphosed by the plutonic masses. The latter in some petrological characters resemble the igneous rocks of the Ben Cruachan complex, considered by Mr. Kynaston to be of Old Red Sandstone age. The breccia is provisionally placed amongst the schists. Mr. Muff.

Several small bosses of diorite, intruded into the schists, are surrounded by distinct aureoles of metamorphism. The black schist and limestone breccia are strongly hornfelsed. The purer limestone is altered to a whitish crystalline marble for several feet from the contact, whilst the argillaceous portions of the limestone have become a calc-silicate-hornfels. The chief soil on the surveyed portion of Lismore is derived from the boulder-clay, which forms a stiff clay soil with stones. Nearly all this ground, together with much that is covered by the gravels of the Raised Beach, forms arable land. Over areas not covered by boulder-clay, the folded limestone rises to the surface in long ridges and hummocks. It weathers along its exposed divisional planes, viz., bedding-planes and a perpendicular set of joints, forming more or less broken-down limestone-pavements comparable with the "clints" of the North of England Carboniferous Limestone. Along the lines of these widened bedding-planes and joints, there grows the bright green vegetation, which affords the pasture, for which the island is so well known, and which causes it to form such a striking contrast with the surrounding heather-clad mountains.

The limestone is now burnt for lime only at Port Ramsay, whence it is shipped to neighbouring coasts. Of the diorite masses, the one at the head of Allt a' Mhuilinn affords a better stone than the others, which are somewhat decomposed. The peat is not cut for fuel. The water supply is derived from springs which are abundant chiefly about the level of the 50 ft. beach. The gravel of the Raised Beach, owing to the springs, does not afford as dry a soil as might be expected.

The islands and skerries off the north and west coasts of Lismore, are composed of folded limestone and black-schist, traversed by dykes, which are similar to those of Lismore. Eilean Dubh, on the east, consists of white and yellow quartz-schist thrown into isoclinal folds, so that all the beds dip to the S.E.

Digitized by Google

Mr. Muff. The rock is mostly fine-grained, a few coarser beds alone containing small crushed quartz pebbles. At the southern end, the strike swings round from a N.E., S.W. direction to one slightly W. of N., and thin-bedded quartzite, with thin partings of green phyllite, appear.

Mr. Kynaston *Glen Creran.*—Proceeding towards the south-east a small area of crystalline schists was mapped by Mr. Kynaston in Glen Creran, in order to complete the survey of Sheet 45 (one inch) for publication. Mr. Kynaston reports as follows:—

"On the east side of the glen the ground rises to 3,000 feet on the granite ridge of Ben Sguliàird, on the west side to about 2,200 feet in the area occupied by the black-schists and quartzites. The river Creran flows through fertile alluvial flats, bounded by steep wooded slopes. The hills are mostly grassy, with but little heather, and so afford good pasturage. The soil on the hill sides is in many parts calcareous, from the weathering of limestone and calcareous hornfels; in other parts there is much sandy material from the weathering of the granite. The population is confined to the glen, and is devoted to sheep-farming and agriculture.

"In continuation of last year's work, the area on the east side of Glen Creran was mapped up to the northern margin of Sheet 45, and the lines were carried on into Sheet 53 as far as Glenure. The schists of this area may be referred to the black-schists, grey phyllites with quartzose bands, and a banded calcareous series like that of the Pass of Brander, with occasional narrow zones of purer limestone. Intrusions of epidiorite are fairly common, but they are usually small and frequently behave rather as dykes than sills.

"The influence of the Ben Cruachan granite, which occupies all the higher ground on the east side of the glen, is distinctly noticeable in the schists, at a distance of nearly two miles from the granite margin. As we approach the granite, the schists become intensely hornfelsed, and constitute the continuation of the hornfels zone, which has been traced to this area from the head of Loch Awe and the Pass of Brander."

Messrs. Peach, Wilson, and Muff. *Kilmartin District.*—In continuation of work done in former years by Messrs. Symes and Hill in the west of Argyleshire, Messrs. Peach, Wilson and Muff, during the autumn, mapped a small area of crystalline schists. The area, which is about two or three miles broad, extends from the western end of Loch Avich in the north, to the Crinan Loch on the south, being bounded on the west by the Barbreck River and Loch Craignish. It includes most of the islands in that loch. The northern part of the area was mapped by Mr. Peach. A small intermediate area lying along the boundary of Sheets 36 and 37 was surveyed by Mr. Muff. With the exception of one square mile at Slockavullin, south of Kilmartin, the rest of the area was mapped by Mr. Wilson.

The Kilmartin area is a portion of the low table-land into which this part of the west of Argyll is carved, irrespective of the nature of the rocks which enter into it.

Digitized by Google

Messrs. Peach, Wilson, and Muff.

Towards the S.S.W. the table-land is about 400 feet in general level, rising gradually towards the N.N.E. to over 1,000 feet, the highest point being attained in Carn Duchara, which is over 1,700 feet in height. This part of the table-land is carved into a series of parallel rocky ridges with a N.N.E. and S.S.W. trend, corresponding to the outcrops of sheets of epidiorite constantly repeated by folding, which resist the weather more effectually than the sedimentary rocks into which they were intruded as sills. The two principal streams which drain the area are the Barbreck River, running into the head of Loch Craignish, and the Kilmartin Burn, a tributary of the Add. Both of these run along the strike in wide valleys, the lower parts of which are hollowed down to below sea level and which are continued seawards as sea lochs. Terraces of alluvium and various raised beaches are found in the lower part of both valleys. The high alluvial terraces of the Kilmartin Burn being partly due to water which drained out of Loch Awe at a period when the upper end of the loch was obstructed by glacier ice and the temporary outlet of the loch was at the S.W. or Ford end. The side streams are necessarily short and steep, and often run along lines of fault or along the courses of basalt dykes, which traverse the area in a N.W. and S.E. direction in great numbers. It is along these lines also that the few narrow passes that cross the area are found.

The table-land is for the most part occupied by rock, but there are a few patches of Boulder Clay and morainic drift, the moraines being only found near the head of the Barbreck River, and on the plateau south of Loch Avich. As a rule the hollows on the table-land correspond with the outcrops of schist of sedimentary origin and are floored with peat or swamps, and an occasional small loch. In the higher regions a thick swathing of peat covers almost the whole surface except the rocky hill tops and escarpments.

The decomposition of the epidiorite gives rise to a scanty soil which, where not covered by peat, supports a grassy vegetation while the peat and quartzite give rise to heath and bents. The higher part of the table-land is, therefore, entirely given over to sheep and grouse moor, while a few Highland cattle are reared. The steeper slopes are often covered with grassy vegetation, especially where, in addition to the *débris* of the epidiorite, the underlying rock is limestone. These slopes are infested with innumerable rabbits, which are trapped and sent to the market in great numbers.

Cultivation is now almost entirely confined to the alluvial terraces and the raised beaches, and is mainly directed to the wintering of the live stock. It has been much more extensive at no distant period and carried well up the slopes, especially where limestone and decomposing epidiorite form the subsoil. Even yet these old cultivated spots form the best grazing grounds in the whole district. In this, as well as in nearly every district in the West Highlands, these patches of old cultivation are overrun with the common bracken *Pteris aquilina*, which is spreading to an enormous extent and spoiling wide tracts of good pasture.

Digitized by Google

Messrs. Peach, Wilson, and Muff.

The population is chiefly confined to the lower parts of the valleys, and is thicker than in most parts of the West Highlands, the mixed grazing and cultivation which the region affords having formed an attraction ever since the first of the Gaels colonised the region early in the present era.

The schistose rocks entering into the area consist of phyllites, limestones, and quartzites, of sedimentary origin, with sheets and dykes of epidiorite and chloritic schists, some of which have undoubtedly been intrusive igneous rocks, and others may probably have been lava flows.

As the area on its eastern border is contiguous with that mapped by Mr. Hill in former years, and as his lines have been continued into the present area, there can be no doubt that the rocks represent Mr. Hill's "Loch Awe Series," and part of the "Ardrishaig Phyllites." It was found desirable to sub-divide the rocks of sedimentary origin further than was carried out by Mr. Hill. The natural grouping of these rocks and their order of succession appears to be as follows:—

(e) Quartzite. Fine grained above and passing down into a coarse pebbly grit below, the pebbles consisting chiefly of quartz, many of them of bluish tinge, and a considerable number of felspar. One small pebble of graphic granite was found by Mr. Muff. The matrix of the grit in places becomes highly calcareous and the rock in places passes down into the following

(d) Pebbly Limestone. A dark limestone more or less sandy throughout, with pebbles of quartz and felspar identical with those found in (e), and with fragments of black limestone, phyllite, black-schist, a few well-rounded pebbles of fine-grained quartzite an inch or two in diameter. In places the limestone becomes a breccia of dark limestone and black-schist fragments.

(c) Limestone. Dark fine-grained crystalline limestone in thin layers intercalated with dark calcareous slates or phyllites.

(b) Black slates and phyllites interleaved with light-coloured siliceous bands and grey phyllites, and passing down by gradual intercalations of grey phyllites into

(a) Grey and green silky phyllites, some of which are sandy.

The rocks of sedimentary origin occupy scarcely half the area, the rest being occupied by epidiorites and later igneous intrusions. Both the schists and epidiorites are thrown into a succession of sharp folds, the long axes of which run approximately N.N.E. and S.S.W. Both limbs of most of the folds dip towards the S.S.E., but there are a few exceptions to this rule where the folds are normal. As well as this minor folding the rocks are arranged on a larger scale in a compound anticline along the eastern border of the area, while the rest of the area forms part of a compound syncline. The result of this structure is that the grey and green phyllites (a) are mostly to be found along the ridge forming the watershed between Loch Awe and Glen Domhain and Loch Avich. Passing westwards from this line these rocks alternate with the dark phyllites (b) and limestones (c), while the pebbly limestones (d) and the quartzites (e) are the chief rocks met with in the centre and west of the area. While this is the general disposition of the rocks,

Digitized by Google

however, the lower rocks frequently show themselves even in the central and western part of the area on the crests of the sharper minor anticlines, so that the whole series cannot be a thick one, even with the addition of the epidiorite sills. Messrs. Peach, Wilson, and Muff.

During the mapping of the area a considerable amount of evidence was obtained to show that the quartzite (e) and the pebbly limestone (d) are unconformable to the limestone (c), the black slates (b), and the grey phyllites (a). The nature of the evidence is twofold. First, the pebbly limestone (d) often contains fragments of the dark limestone (c) and dark phyllites (b), where the two rocks are adjacent to each other, and the bottom beds of the pebbly limestone (d) sometimes consist of a breccia of these two rocks. Grey silky phyllite fragments, like those of group (a), also occur both in the limestone and the quartzite. There can be no doubt, therefore, of the derivative nature of the bed, while in numerous sections the pebbly limestone (d) is seen to shade up through calcareous grits into the quartzite (e). Second, the quartzite, which usually overlies the pebbly limestone, in places overlaps it and rests on the black slates (b) and limestones (c), and even on the grey phyllites (a). The calcareous grit or pebbly limestone also transgresses the edges of the underlying rocks in places. The evidence, therefore, is very much in favour of an unconformability between the quartzite and pebbly limestone on the one side, and the limestones and phyllites on the other.

Epidiorites, occurring chiefly as wide spread sills folded with the sedimentary schists, occupy more than half the area. Two different types can be made out on the ground:—

1. A fine-grained rock, slaggy and highly vesicular at its margin, sometimes showing an arrangement of phacoids with vesicular outer layer and a non-vesicular interior suggestive of the "pillow structure," visible in certain lava flows. Sills of this rock are usually associated with the phyllites and limestones and apparently produce little or no metamorphic action upon the neighbouring sedimentary rocks. In part of the area they are continuous with rocks already reported on by Mr. Symes (*Summary of Progress* 1899, pp. 61, 62) and Mr. Kynaston. Their likeness to certain basic lavas has been noted by Mr. Teall (ibid. *Summary of Progress*, 1900, pp. 33, 42, 44, and footnote p. 34).

2. A more massive rock, coarse in texture, and with few or no vesicles. These sills are usually associated with the limestones and quartzites, and produce a certain amount of contact metamorphism, converting the impure limestones into calc-silicate hornfels. A sill which extends over a considerable area in Glen Domhain, where it is intruded into the quartzites, is so full of large porphyritic felspars that it looks as if it had been an andesitic rock prior to its alteration. All the epidiorites are in places more or less foliated, and chlorite, epidote, and zoisite are the most common minerals. All are more or less calcareous, and in the slaggy portions the amygdules of calcite make up half the bulk of the rock. The microscopic characters of the above type of rocks have been already given in Mr. Kynaston's report for 1900. *Summary of Progress* for 1900, pp. 32–35. Mr. Hill has also described the characters of these rocks as developed in ground adjacent to the present area. *Summary of Progress*, 1900, pp. 41, 42.

Crush, or pseudo-conglomerates were observed by Messrs. Peach, Wilson, and Muff in ground mapped by them respectively. They occur generally where the pebbly limestone is associated

Digitized by Google

Messrs. Peach, Wilson, and Muff.

with sills of epidiorite. From the fact that what appear to have been continuous bands of shale are now represented by rows of isolated phacoids or **S**-shaped masses of slate in a pebbly limestone matrix, we are inclined to accept Mr. Hill's explanation for part, at least, of the phenomenon. Mr. Muff, who has mapped the best examples, gives the following description of what occurs in his area.

Mr. Muff.

"The structure described by Mr. J. B. Hill, under the name of 'crush conglomerates,' has been met with in several localities in the pebbly limestones usually near the junction of that rock with epidiorite. More or less lenticular blocks of epidiorite, whose long axes are approximately parallel, lie inclined at high angles to the line of junction. The best exposure occurs at a cliff 1,200 yards north by east of Salachary. Two undulating bands of phacoidal masses of epidiorite, commonly between six inches and one foot in length, and with highly inclined long axes, cross the face of the pebbly limestone. A third, but shorter, belt is composed of phacoids of black slate embedded in the limestone." Mr. Muff is also of opinion that some of the vesicular phacoids found in the fine-grained epidiorite may have had a similar origin. He reports on them as follows:—"An Samhladh, and the ground to the north-east is composed of folded schistose epidiorite, which contains bands of uncrushed vesicles filled with calcite. In many places, lenticular masses, up to two feet in length, consisting of an outer coat of vesicular epidiorite, and an inner core of more schistose epidiorite, lie with vertical long axes, in schistose epidiorite, the planes of schistosity of which conform more or less to the edge of the lenticular masses. It is possible that these lenticular masses have been formed by the nipping off of the crests of the folds composed of an outer coat of highly vesicular and an inner core of strongly schistose epidiorite."

TORRIDONIAN.

Mr. Clough.

Island of Soay.—In order to complete the Survey of Sheet 70 (one inch), Mr. Clough undertook the mapping of the Torridonian rocks of the Island of Soay, and has supplied the following report:—

"The Island of Soay, though nearly all composed of bare rock and peat, is conveniently situated for the herring and the lobster fishing. The population is consequently not so sparse as in many parts of the Highlands, and it diminishes in summer, as many of the younger men are then away, engaged on yachts and tourist steamers.

"The island is essentially composed of Torridonian rocks, and of Tertiary intrusions. The Torridonian rocks dip somewhat steadily W. at about 15°, and are not altered nor veined with quartz, and there is nothing to suggest folding or thrusting. They are divisible into three groups, which are as follows, beginning at the top:—

Digitized by Google

"1. Leac Faoileann group. Pale pink, rather fine-grained false-bedded grits. Thickness about 270 feet. Top not seen. Mr. Clough.

"2. Beinn Bhreac group. Red and purplish red false-bedded grits, with pebbles from half an inch to two inches long, of quartzite, felsite, andesite, and jasper. Thickness about 2,200 feet.

"3. Leac-Stearnan group. Pale pink false-bedded grits, with thin bands of grey sandy shale. Thickness about 900 feet. Base not seen.

"The rocks in group 2 closely resemble those in the Applecross group of the mainland."

A large N.W. fault cuts the island in two, with a downthrow on the N.E. side about 700 feet. This fault does not appear to affect the plateau basalts on the north side of the Sound of Soay, and it is probably of pre-Tertiary age. Another fault, tending N.N.W., passes a little east of Beinn Bhreac, and has a downthrow to E.N.E. of about 90 feet. The fault seems of earlier date than a thin sill of porphyritic basalt. Various other faults can also be proved to have taken place prior to certain igneous intrusions.

Isle of Skye.—Mr. Wedd, while mapping the Secondary rocks in the Sconser, Loch Sligachan, and in the Strathaird Districts of Skye for the completion of Sheet 71, met with some small inliers of Torridonian rocks. Owing to their isolation there is no direct evidence as to the exact subdivision of the formation they belong to, but there is no doubt as to their Torridonian age. Of these inliers Mr. Wedd reports as follows:— Mr. Wedd.

"Near Sconser, this sandstone, hard and compact, sometimes coarse and pebbly, either pink and felspathic or light grey, lies in an anticlinal fold on and below the northern slope of Glamaig. It is brought up again further west by N.W. faults at Glac Fhearna. In Strathaird, Torridon rocks occur at Camasunerie. They consist in part of hard, fine, and coarse-grained, compact sandstone, often pebbly, and changing irregularly from light grey to pink, with many grains and pebbles of felspar, and of very hard finely laminated shales. At Camasunerie the shales occur only as thin layers in the sandstone, but west of Camasunerie they form thick beds underlying massive sandstone. The relation of these thick shales to the rest of the Torridon sandstone of Camasunerie is obscure."

CAMBRIAN.

Metamorphosed Cambrian dolomites of Strath in Skye.—A re-examination of the metamorphosed equivalents of the Durness Limestone group in Skye became desirable in the light of Mr. Teall's work on the similar rocks at Ledbeg in Sutherland and Dr. Pollard's chemical investigations published in the *Summary of Progress* for 1900. The metamorphism is exceptionally well displayed in the vicinity of the Tertiary granite and gabbro of the Broadford district. Accordingly Mr. Harker revisited these localities in conjunction with Mr. Tait, who collected a typical series of specimens. Mr. Harker.

The results go to show that the rocks must have been in great part dolomitized, and often completely, prior to the igneous intrusions, and have been more or less completely dedolomitized

Digitized by Google

Mr. Harker. by metamorphism in the manner described by Mr. Teall (*l.c.* pp 153, 154). The dolomite has been reduced to calcite, the magnesia giving rise to other minerals. A common type among the resulting marbles is a rock consisting of calcite and forsterite, the latter often in perfect crystals, which show prominently on a weathered face. From this type come also at least the majority of the serpentinous marbles or "ophicalcites" of the district, the serpentine being derived from forsterite, which is often seen partially destroyed. Other minerals found in varieties of the marbles are diopside, tremolite, white mica, idocrase, and a violet spinel. Such rocks must have been originally impure, chiefly owing to disseminated chert, but pure dolomites have also been dedolomitized. The result in this case is a pure white rock consisting simply of calcite and brucite, and comparable with the "pencatite" of Predazzo in the Tirol. It seems probable that periclase was first formed, and has been converted to brucite by hydration; but neither periclase crystals nor unmistakable pseudomorphs after them have been detected.

LOWER OLD RED SANDSTONE.

Messrs. Peach and Kynaston. *District of Lorne.*—In order to complete Sheet 45 (one inch) with a view to its publication, the remaining unsurveyed portion of the Lorne Volcanic Plateau, which enters into that sheet, was mapped by Messrs. Peach and Kynaston during the season.

In the autumn and early winter, Mr. Peach, in intervals between other duties, mapped a small area round Loch Nell and the head of Loch Feochan.

Mr. Peach. *Feochan Area.*—The area surveyed by Mr. B. N. Peach during the year is part of the Lorne Volcanic Plateau which here rises to a general level of over 500 feet, the greatest height being over 900 feet. The plateau is trenched almost to sea-level by the two branches of the Feochan River which runs into the head of the sea loch of the same name. The floors of the valleys in which the rivers run are flat and their sides steep showing a step-like series of escarpments corresponding to the outcrops of the successive lava flows. The side streams join the main valleys through deep straight-cut ravines, which coincide either with lines of fault or with igneous dykes, the shattered rocks and decomposing dykes being more readily removed by the streams than the more solid andesitic lavas which they traverse.

The surface of the plateau is for the most part very irregular and almost bare of drift but, in some of the hollows and flats, there is a sparse coating of morainic material which is usually covered with peat and gives rise to a heathy vegetation. Above the general level there rise irregular rocky tops with the characteristic stair-like escarpments. Towards the western portion of the ground, the surface of both the flats and the rocky hillocks is dotted with moraines. Some well-defined trains of boulders are strewn across the ground and can be traced up to their parent rocks, which always lie to the westward of the trains, while the

Digitized by Google

sources of others, such as those of the Cruachan granite blocks, lie outside the present area. The varied conditions of the plateau give rise to a mixed vegetation favourable for sheep grazing and for summer grazing for the hardier varieties of young cattle and horses. On the sides of the valley and between the escarpments where the slopes are not too steep, the disintegrated igneous rocks produce a thin soil which gives rise to a scanty but sweet vegetation, affording summer grazing for cattle and sheep; while the cultivation is almost entirely restricted to the alluvial lands and the raised beaches which floor the valleys, but the ground is at present cropped mainly to support the live stock. Dairy farming is carried on by some of the farmers as there is a great demand for milk during the tourist and yachting season at Oban, which is within easy reach. The population which is entirely occupied in farming, is sparse and confined to the valleys. Mr. Peach.

The climate is mild and wet, and as there are several lochs along the course of the streams there is a constant supply of good water both summer and winter. Copious springs issue on the sides and bottoms of the valleys, chiefly from the fault-breccias and lines of dykes which traverse the andesites in large numbers

Trees, both conifers and hardwoods, grow luxuriantly where sheltered from the sea winds, even upon the steep *débris* covered hill-sides, and sometimes on the rocky escarpments themselves.

The andesitic lavas supply material for drystone dykes and rubble for masonry, and the harder varieties afford good road metal, but the best road metal is obtained from the dolerite and basalt dykes which traverse the area in great profusion. The numerous boulders of Cruachan granite which are strewn over some parts of the area afford excellent material for corner stones, lintels, and such work where massive stones are required.

The raised beaches and alluvial deposits afford a good supply of gravel and sand for concrete and mortar.

Peat occurs in considerable amount both on the plateau and on the 100-feet raised beach, but is not at present much worked as coal is found to be more economical.

The prevailing rocks in this area are andesitic lavas, some coarse conglomerates, and fine tuff and basement conglomerates, and red and grey shales.

These rocks are arranged as follows: The basement conglomerates, overlain by red and grey shales like those of Oban, here rise on a low dome from beneath the andesites at the south end of Loch Nell and are visible on both sides of the loch. In the high plateau lying between Loch Nell and the foot of Glen Lonan, and the Feochan Bheag, the grey shales are succeeded by andesitic lavas which dip gently to the south and east from off the dome, being only separated from each other, in most cases, by their own slaggy upper and under surfaces, and forming a succession of craggy escarpments. One thin zone of agglomerate, tuff, and red shale, lying at a level of 300—400 feet from the base, has been traced from Torr an Tuirc near the head of Loch Nell, by Barnacarry and Kilmore to near Kilbride. Above this zone shattery

Digitized by Google

Mr. Peach. fine-grained andesite flows form successive escarpments for a few hundred feet, and are then succeeded by massive coarse porphyritic hypersthene-andesites which cap the highest ground and cross the area from Kilmore to Glen Lonan. Lava flows of this type are succeeded to the east of the present area by a zone of mica-andesites of more acid character, which were mapped by Mr. Kynaston and are described by him.

In the small area south of the head of Loch Feochan mapped by Mr. Peach, successive flows of basic andesite dip gently towards the north-west.

Both of the above areas are traversed by dykes of hornblende-porphyrite, quartz-felsite, and lamprophyre, of the same general age as the lava-flows. This appears to be the northern edge of a zone where the dykes are increasing in number southwards from the present area. Both the lavas and these dykes are cut by numerous basic and acid dykes with a north-west and south-east trend which are probably of Tertiary age.

Mr. Kynaston *District between Taynuilt and Loch Scamadale.*—This area consists almost entirely of hilly ground, rising to a height of nearly 1,700 feet above sea-level, and is occupied by the Lorne volcanic series. It constitutes essentially a denuded lava-plateau, intersected by small, though often steep-sided glens. The slopes of the hills are often terraced by well-marked lines of crag and escarpment indicating the outcrop of successive flows, while the higher ground frequently forms an uneven heather-covered table-land, throughout which numerous knolls and crags of rock stand out among peaty and marshy hollows.

The lavas, especially the more basic types, are usually much decomposed and disintegrated, and break off readily into small angular fragments. The rock takes on a yellowish or brownish crust, and is purple, or sometimes brick red on fracture, in contrast to the almost black colour of the fresher varieties.

The soil is thin and poor, almost the entire area being given up to grouse moors, and sheep pasturage. The only portions under cultivation are the alluvial flats in the glens, and the raised beaches and river terraces, where the soil is good and fertile.

The rock is often quarried for road metal, and for stone walls, and occasionally for building purposes.

The population is restricted to the glens and the low ground near sea-level.

In the Taynuilt area the general dip of the volcanic series is south-east, and it is often possible to map out individual flows and trace them for some distance. To the west of Taynuilt a considerable area is occupied by a dark purple andesite, with porphyritic crystals of plagioclase and greenish pseudomorphs after hypersthene. This rock is well seen in a roadside quarry, 1½ miles north-west of Taynuilt, also in Airds Park, whence it may be followed across the wooded ground to the south-west to the conspicuous hill of Deadh Choimhead, on the north side of Glen Lonan. Apparently beneath this flow we find in Airds Park a much more acid type of rock, similar to the felsitic lavas

Digitized by Google

of Glen Nant, described in the *Annual Summary* for 1897, p. 84. As in Glen Nant we have here also a finely banded structure due to flow, and the occasional occurrence of a coarsely spherulitic or nodular variety, with numerous nodular bodies up to about half-an-inch in diameter. The same rock is again well seen south-west of Taynuilt, to the west and north-west of Balindore, and forms the wooded knoll west of Barguilean. Flow brecciation is occasionally seen, and there is, as in Glen Nant, a frequent association with hornblende and mica andesites. To the south of Taynuilt and on the west side of Glen Nant, the felsitic lava is again well exposed at and near Taylor's Leap, together with hornblende- and mica-andesites. Mr. Kynaston

Beneath the felsitic lava there is a dark grey compact andesite, which appears to cover a considerable area immediately to the south-west of the Taynuilt raised beach. This is a more basic type of lava than the hypersthene andesite, noticed above, only rarely showing porphyritic felspars and containing numerous specks of the reddish-brown mineral (?iddingsite) which occurs mostly as pseudomorphs after olivine. Beneath this basic flow we find conglomerates with some red shales and gritty beds, seen in numerous exposures south-west of Taynuilt. The conglomerate shows a high proportion of quartzite boulders, andesite boulders being also common, though more local.

Interbedded with the basic andesite of Airds Park, N.N.W. of Taynuilt, we have a band of an acid tuff. It is compact and flinty in texture and varies in colour from reddish-purple to a pale yellowish. It is often crowded with small fragments of felsite, with some of andesite, and shows biotite flakes and crystals of an acid felspar. A precisely similar tuff is again seen in the higher ground further south, cropping out below the upper crags of Cruach Ard-dhuine, where it is intercalated between narrow bands of red shale and sandstone.

The lavas, both above and below the bands of sediment, are of a basic facies, and may be referred to either felspathic types of olivine-basalt or a very basic andesite. The lower flow rests upon conglomerate, and is highly vesicular towards its upper portion.

Farther to the south-west, and in the area south of the upper part of Glen Lonan, the normal lava is a somewhat basic andesite, which, in the higher part of the area, is capped by a well-marked flow of mica-andesite. This latter constitutes the upper part of Carn Gaibhre, and stands out conspicuously in the crags of Creag-an-Fhithich to the south. It is again well seen on the south side of Beinn Ghlas, and covers a considerable area to the north-west of Lochan Dubha. The rock is often felsitic and shows flow-banding. Flow-brecciation is also very common, numerous angular felsitic fragments being embedded in a reddish matrix. The rocks which overlie the mica-andesite are well seen in a crag section half-a-mile north of Lochan Dubha. Resting upon it we have a flow of basic andesite, allied to basalt, above which is a well-marked band of andesitic agglomerate and ashy material, overlying which is a purple porphyritic (?) hypersthene-andesite.

Digitized by Google

Mr. Kynaston The agglomerate appears again on the west side of Lochan Dubha and is well exposed in the conspicuous Creag Mhor, south-east of Kilbride in Glen Feochan, and has been followed for some distance above the mica-andesites on the south side of Glen Lonan. Its fragments consist entirely of different varieties of andesite in a finely fragmental matrix. They are occasionally more or less rounded and often attain a diameter of 4 or 5 feet.

The basic lava below the agglomerate is often highly vesicular, the vesicles being represented by amygdules, often as large as hens' eggs, of reddish agate with an inner layer of crystalline quartz.

South of Kilbride, in Glen Feochan, the high ground (Creag Ghlasrach, Righ Roc, etc.) consists of a dark purple porphyritic andesite, with numerous phenocrysts of plagioclase and a green mineral, probably a pseudomorph after hypersthene. The rock is often very vesicular, but the non-vesicular portions often closely resemble the intrusive porphyrites, owing to the comparatively large size of the phenocrysts and the reddish colour of the weathered surface. This type of flow covers a considerable area south of Kilbride, and is continued to the north side of Loch Scamadale.

Further east, in the region about the Sior Lochs and Beinn Dearg, east and south-east of Musdale, considerable masses of tuff have been mapped and were seen to be bedded between rather basic types of andesite. This is a rather less acid tuff than that of Airds Point and Cruach Arddhuine, and is similar to the rock mapped by Mr. Symes near Achnacloich, and by myself near Taynuilt and already described.*

Mr. Peach. The volcanic rocks in this area must rest on a very irregular floor of older rocks, for an elongated inlier of black shales and limestones (see *ante*, p. 124) rises from beneath the porphyritic lavas near Kilbride, which must be separated from the basement rocks visible on Loch Nell by a thickness of more than 1,000 feet of basic lava flows, the edges of which must abut against this old floor of schistose rocks.

Mr. Kynaston Inliers of the older rocks are seen in several places in the area about Loch Scamadale, one to the south-east of the head of the loch, above Fineglen, occurring at an altitude of over 1,100 feet, and forming the bed and slopes of a portion of the glen. These inliers afford interesting evidence of the kind of surface over which the lavas were poured out.

An important result of the mapping has been the recognition of the wide distribution of more acid types of lava-flow, such as hornblende-and mica-andesites and felsites, and various pyroclastic rocks. This may serve to connect the Lorne series with that of the Blackmount and Glencoe, where the more acid types are a characteristic feature. We may note, too, the not infrequent observation of basic having succeeded more acid material.

---

* "On some Tuffs associated with the Andesitic Lavas of Lorne." *Trans. Edin. Geol. Soc.*, vol. viii., p. 87.

Digitized by Google

In the *Summary of Progress* last year, p. 71, Mr. Kynaston described the induration noticeable in the andesites and conglomerates as they are followed towards the Pass of Brander. This year he obtained further evidence of a similar kind at the north-west end of the Pass. Thus, in the railway cutting close to the Awe Viaduct, intercalated in the andesites, is a band of laminated shales and grits, the induration of which is very marked. The granite is not more than three-quarters of a mile from these beds, a distance at which it may well have indurated the sediments without appreciably affecting the andesites. At the entrance to the Pass of Brander the andesites are well exposed on the south-west side, and appear to be decidedly indurated, and show small veins and bands, a few inches in breadth, of a rock allied to porphyrite, but approaching microgranite in texture. Above the cliffs on this side there is a band of conglomerate and grit, which again shows decided induration. Mr. Kynaston

Dykes and Sills.—Dykes and sills, belonging to the same volcanic period as the lava-flows, are exceedingly numerous throughout the greater part of the area mapped, and maintain, as a rule, the usual N.N.E. and S.S.W. trend. The mapping has shown that the area most thickly intersected by these intrusions constitutes a kind of belt or zone, about a mile in breadth, stretching from the area immediately south of Taynuilt to the high ground south of Loch Scamadale. The intrusions are mainly hornblende- and biotite-porphyrites, similar to those described in former reports. Occasionally more basic types are found, often closely resembling the normal andesitic lavas, while more acid varieties have affinities to quartz-porphyry. Intrusions of quartz-porphyry, cutting the andesites, have been mapped in several places in the area S.W. of Taynuilt, and closely resemble those occasionally associated with the Ben Cruachan granite.

Dykes allied to lamprophyre have also been observed, though they are not common. North-east of Loch Scamadale a dyke occurs closely resembling a mica-diorite. Another dyke, of unusual type in this district, occurs in Glen Nant, a quarter of a mile south of Tailor's Leap. The rock is allied to the hyperites, and may be termed a hypersthene-diorite-porphyrite. It shows under the microscope [9652], large phenocrysts of zoned plagioclase, idiomorphic hypersthene altered to bastite, and pale greenish augite, in a granular ground-mass of plagioclase with some alkali-felspar and a little quartz. Such dykes form connecting links between the andesitic lavas, and the hyperite modifications of the granites.

Kingshouse area (*Blackmount and Royal Forests*).—This area is a wild mountainous tract, the highest point of which rises to slightly over 3,600 feet, and is occupied by the Blackmount and Glencoe volcanic series and granite. On the east, the wide stretches of peat, and moraines of the Moor of Rannoch, are in striking contrast to the conspicuous heights about the head of Glen Etive and Glencoe. Mr. Kynaston

Among the volcanic rocks, the hornblende-andesite weathers with a pale grey or whitish crust, and forms conspicuous crags,

Digitized by Google

Mr. Kynaston often much broken up by joints, so producing much scree material. The breccia and agglomerate is more massive, and weathers into comparatively more rounded masses with a rough surface, and breaking away in large angular blocks. The felsite forms striking precipitous crags, with well-marked vertical joints, and disintegrates into sharp angular flinty fragments. The granite forms rounded hill-tops, often flanked by steep crags with characteristic jointing.

To the east lies the western portion of the Moor of Rannoch—a table-land with a granite floor, weathering to a fine quartzose sand, covered by moraines and peat-mosses, while in the hollows lie numerous lochs and lochans, showing varying degrees of silting up. The peat, where of good quality, is used for fuel, also the numerous stumps of Scotch fir which occur in it so abundantly.

There is no cultivation, the ground being entirely deer forest.

Volcanic Rocks.—The mapping of the volcanic area to the north of the Clach Leathad was continued by Mr. Kynaston during June from Kingshouse. The principal types of rock which constitute the volcanic series have already been described in the *Summary of Progress* for last year, so it will be sufficient here to give a summary of the more recent progress of the work as regards the behaviour and relationships of the rock-masses, with a brief account of certain fresh facts of interest. The mapping of the rhyolitic felsites, breccias, and hornblende-andesites of the long north and south ridge, on the north side of the Clach Leathad, was completed. The andesites occupy the highest ground and form a roughly oval area, invaded on its south and west sides by the Blackmount granite. The rocks are mostly typical hornblende-andesites, though augite-bearing varieties also sometimes occur. On the north and east sides of Stob Glas Choire a zone of 20 to 30 feet of dark grey laminated shales and grits was found intercalated in the andesites. The beds are much indurated by the granite. Below the andesites we find the breccias, apparently underlying them in a normally bedded manner. In its upper portion the breccia is often of finer material, and occasionally shows gritty bands, and well-marked signs of bedding. The breccias sweep round the northern margin of the andesites, capping the ridge at Sron Creise, and thence bend round to the south-west and are cut off by the granite. While examining the breccias in detail in two or three places, Mr Kynaston found fragments of a rather acid biotite-granite, resembling that of the Clach Leathad. That they were derived from the granite of the Blackmount is, however, not possible, since this latter is clearly itself intrusive in the breccias.

The rhyolitic felsites are seen apparently underlying the breccias on the north-east spurs of Stob Glas Choire and below the summit of Sron Creise. They rise up in precipitous crags on either side of the Càm Ghleann, and thence stretch north westwards, below Sron Creise, to the river Etive, being terminated abruptly to the south-west by the intrusion of the granite. From the river Etive the felsites were traced further north-west and

Digitized by Google

were found to be continuous with the felsitic masses of the Buachaille Etive Mor. Along its north-east margin the felsite shows a sharply defined junction with the older schists. The contact face of the igneous rock is usually vertical or almost so, and behaves apparently as an intrusive rock, and often shows a narrow border of breccia. Outside the margin, small oval-shaped and dyke-like intrusions of the felsite are common in the schists, and in the Càm Ghleann occur two small plug-like intrusions of augite-andesite. Mr. Kynaston

Passing to the Buachaille Etive Mor, on the north-west side of Glen Etive and west of Kingshouse, we find evidences of bedding well indicated. Thus at the foot of the north-east crags of Stob Dearg the base of the series is formed by a bed of conglomerate (15 feet), resting upon the schists, and overlain by reddish and purple shales. Above the shales lie bedded conglomerate and breccia, which are overlain by the rhyolitic felsites. Practically the whole of the east face of Stob Dearg consists of different varieties of felsites. The rocks show a most perfect flow structure, and flow-brecciation is common. About half-way up the east face a band of dark purplish and greenish shales is seen in the felsites, and coincides with part of an obliquely descending line of feature called the "Crowberry Traverse." These beds are again well seen in the bed of the gulley immediately south-east of this feature. On the north side of Stob Dearg the breccias are well bedded and contain gritty bands.

The intercalations of sediment above described closely resemble, both lithologically and in mode of occurrence, the sedimentary bands so common among the lavas of Lorne, and constitute strong evidence that the volcanic series of the Blackmount and Royal Forests is of the same age as that of Lorne. The shales of the "Crowberry Traverse" closely resemble the indurated sediments seen in the railway cutting near the Pass of Brander.

As already stated, the granite of the Blackmount is seen cutting each member of the volcanic series along the western slopes of the Sron Creise ridge. The contacts are remarkably clear, and the evidence of the alteration of the volcanic rocks has been established beyond any room for doubt, both in the field and with the microscope. Veins of granite and pegmatite are sometimes seen traversing both the andesites and the breccias, and the granite veins occasionally contain fragments of the breccia. It is obvious, therefore, that the fragments of granite in the breccia must evidently have been derived from an older granite mass, or may indicate an earlier plutonic phase belonging to the same period of igneous activity. A parallel case may be found in the occurrence of fragments of granite and gabbro, in the agglomerates of the Cuillin Hills of Skye.*

* See Harker, "The Sequence of the Tertiary Rocks of Skye," *Geol. Mag.*, Dec. 4, vol. viii., p. 507.

Digitized by Google

Mr. Kynaston

Dykes.—The final period of eruptive activity was marked by the formation of numerous dykes, with the normal N.N.E. and S.S.W. trend. These are mostly of hornblende and mica-porphyrite, but quartz-porphyry and andesite are not uncommon. The resemblance between these dykes and the similar types of intrusion which cut the Lorne andesites and the Ben Cruachan granite, is so close, and their behaviour and intimate association with acid and intermediate lavas and plutonic masses so similar, that one can hardly doubt that they belong to the same period of vulcanicity. Intrusions of lamprophyres, or allied rocks, are comparatively rare, only one case having been noticed this season, namely of a rather basic rock allied to camptonite, cutting the schist on the north slopes of Sron Creise.

Glen Creran, Ben Cruachan Granite.—The mapping of the western margin of this granite was continued by Mr. Kynaston from Glen Creran, and the boundary line was traced from Coire Buidhe, east of the head of Loch Creran, along the western slopes of Ben Sguliaird to the upper part of Glenure. The larger portion of the rock is a biotite granite, relatively poor in hornblende, while a more acid pink granite is frequently exposed on the higher ridges of Ben Sguliaird. Inclusions of hornfels are common.

In the upper part of Glenure, N.N.E. of Ben Sguliaird, is a mass of augite-diorite, of a type formerly observed in Glen Strae. It extends from the south bank of the river Ure up to the granite margin on the slopes of Ben Sguliaird. It does not pass into the granite, but appears to be interbanded with it in a rather complicated manner. The same rock is again seen along the granite margin on the north side of An Grianan, and doubtless represents a more basic modification of the same magma from which the granite was derived.

Associated dykes in the Glen Creran area, as yet mapped, are confined to a few small lamprophyres.

Mr. Muff.

Lismore Granite Masses.—During the mapping of the metamorphic rocks in the north of the Island of Lismore, in Sheet 45 (one inch), Mr. Muff met with several small bosses of plutonic rock in which were represented several rock types similar to or identical with those found round the margin of the "Cruachan" massif. These are associated with a similar set of dykes like those surrounding the Cruachan area. Both sets of rocks are in turn cut by one or more types of Tertiary basic dyke. A strong presumption is, therefore, raised that these rocks belong to the same general period of intrusion as the Cruachan granite.

Mr. Muff supplies the following description of these bosses and dykes in Lismore:—

"Four plutonic bosses of small size appear within the area. The first forms a small promontory on the west side of the island a quarter of a mile north of Sliabh nam Ban-fionn. Its form, as shown in the cliffs, is that of a blunt cone with concave slopes. A second boss rises as a dome-shaped hill immediately N.E. of

Digitized by Google

Sliabh nam Banfionn. A third occupies the circular hollow at the head of Allt a' Mhuiliun, and is surrounded by high walls of altered limestone. It is crossed by a Tertiary basalt dyke. Two small outcrops on the side of the large peat moss at Sron-na-Craoibhe probably belong to a fourth boss. Mr. Muff.

The rock composing those bosses appears to be typically a medium grained augite-diorite, usually with abundant biotite. Hornblende often surrounds the pyroxene and a very little quartz is present. A specimen from the head of Allt a Mhuilinn containing rather more quartz and abundant orthoclase, shows a passage to the tonalites. The boss near Sron-na-braoibhe and that a quarter of a mile N. of Sliabh nam Ban-fionn exhibit basic marginal varieties. A specimen from the latter (10,106) described by Dr. Flett as "an augite-biotite-diorite-porphyrite, shows large idiomorphic phenocrysts of pale green pyroxene, abundant porphyritic biotite less perfectly formed, remains of serpentine after olivine, and a ground-mass of hypidiomorphic plagioclase and orthoclase. In some respects it resembles a kentallenite." Several small veins of aplite which contain an unusual amount of plagioclase cut this basic margin of the boss, but basic varieties are not always present along the margins. Near the contact of the boss mentioned second above with the limestone breccia, a fine-grained augite-porphyrite is seen. The latter has injected abundant irregular veins into the former, whilst the igneous rock is crowded with fragments of limestone and limestone-breccia. All these bosses are accompanied by aureoles of metamorphism which are narrow in the purer limestone, but broaden out in the argillaceous limestone and black schist. The purer limestone is converted into a whitish marble for several feet from the contact, whilst the impure limestone forms a calc-silicate-hornfels.

Amongst the numerous dykes, it appears possible to recognise (1) a set of N.E. lamprophyre dykes, (2) irregular mica lamprophyre dykes, (3) a set of dykes varying in composition from basalts to andesites which traverse the island from W.N.W. to E.S.E. and are probably of Tertiary age. The north-easterly lamprophyre dykes appear to be vosgesites. They are very irregular, sometimes appearing as branching dykes, sometimes as a string of lenticular masses, end to end. A certain small amount of movement appears to have taken place subsequent to their intrusion. On the low promontory immediately west of Port Ramsay, and elsewhere, the W.N.W. basaltic dykes cut them. It has not been shown that these lamprophyre dykes cut the plutonic masses, but apparently they enter the aureole of metamorphism without undergoing alteration.

The mica-lamprophyre dykes include the largest dykes in the area, the best examples appearing on Eilean Ramsay and the neighbouring skerries. It cannot be said that they follow any particular direction. They are younger than the plutonic masses, for not only is an unaltered dyke seen to penetrate the metamorphosed limestone, but small lamprophyre veins cut the diorite.

Digitized by Google

Mr. Peach. *Glen Domhain Granite.*—While mapping the crystalline schists in Glen Domhain, near the edge of Sheets 36 and 37 (one inch), Mr. Peach traced for over a mile the southern and eastern boundary of the granite mass mentioned by Mr. Symes in the *Summary of Progress* for 1900, p. 49. The mass is fine grained near its edge, and often of a rather basic type, resembling the hyperites that are found near the margins of the Galloway granite masses. The alteration in the schists and epidiorites is intense close up to the granite, but dies out within a comparatively short distance, and is similar to that described in former summaries.*

TRIASSIC.

Mr. Wedd. *Isle of Skye.*—In order to complete the mapping of the Secondary formations in that part of the Island of Skye which enters into Sheet 71, Mr. Wedd resumed the work of last year, as reported in *Summary of Progress*, 1890, p. 113. His work was carried on in four separate districts—(1) Sconser, on Loch Sligachan; (2) Strollamus and south of Scalpay; (3) Strathaird and Torran; and (4) the district of Strath between Lochs Slapin and Eishort.

Rocks of Triassic age were met with in two of these localities, viz., Sconser and Strathaird. About Sconser they consist of conglomerate, made up of pebbles of Durness (Cambrian) limestone and chert and Torridon sandstone, red sandstone, and red and light green marly beds, the conglomerate predominating near the base. At the top there is often a bed of hard fine-grained light green sandstone. In this area these rocks are often much metamorphosed. At a point 300 yards E. of the second milestone from Sligachan in a burn section some thin, soft, light marly sandstone lying between two igneous sills, overlying a hard, coarse, blue-streaked grit, and underlying the lowest Lias limestone, may probably represent the thin beds provisionally assigned to the Rhætic in Strath.†

In the district of Strathaird (3) a thin quartz conglomerate occurs at the S. end of Blath Bheinn. On the west side of its southern spur, a thin blue limestone conglomerate is visible beneath the base of the highly metamorphosed Lias. These conglomeratic beds probably both belong to the same group as the beds assigned to the Trias which occur elsewhere in Skye.

JURASSIC.

LOWER LIAS.

Isle of Skye.—The Lower Lias in the Sconser district consists of thick micaceous shales and beds of calcareous micaceous sandstone, both with Arietite Ammonites and *Gryphæa arcuata*. Below these is a thin series of blue limestones, with shale near the top, two coral beds near top and bottom, bands of *Gryphæa*

* *Summary of Progress* for 1899, p. 63; *Ibid*, for 1898, p. 86.
† *Summary of Progress* for 1900, p. 113.

Digitized by Google

near the top, and a bed of small oysters near the base. The lime- Mr. Wedd.
stones are perhaps not much more than 30 feet in thickness. No separate division of calc-sandstone at the base can be recognised as in the Broadford beds, neither can the sandstone which immediately overlies the limestones be found. The *Bucklandi* and *Semi-costatus* beds are recognisable. In district (3), N. of Torran, highly metamorphosed blue limestones with beds of shales in the upper part, and possibly a coral bed, dip steeply towards the S. and S.W. from off the granophyre on either side of the Strath Beag. They are succeeded by thick micaceous shales with sandy beds, considerably metamorphosed. The shales contain obscure ammonites and pectens, not yet determined, and in the upper part, beds of *Gryphæa*. It is clear that here is the lower part of the Lias, but it is difficult to say how far up in the series the strata extend. In Strathaird, N. of Camasunerie, Lower Lias occupies the upper part of the valley of Abhuinn near Leac, and forms the lower slopes on the E. and W. sides of the south spur of Blath Bheinn. It is intensely metamorphosed by the plutonic rocks, and also by innumerable dykes. It consists of thick shales and sandstones overlying thin blue limestones intercalated with shales and containing bands of *Gryphæa* with thicker limestone below. The whole is highly metamorphosed, but the few traces of ammonites obtained, together with the beds of *Gryphæa*, are enough to show the Lower Liassic age of the series. A little patch of the same limestone was seen near the mouth of Abhuinn Camas Fhionnairidh. In the Strath district (4) Lower Lias has been mapped, as usual a thick series of micaceous shales and micaceous sandstones with *Gryphæa*, &c., above thin blue limestones with thin shales, along the east shore of Loch Slapin and the north shore of Loch Eishort. The *Bucklandi* and *Semicostatus* beds are recognisable.

UPPER LIAS.

Isle of Skye.—A small exposure of Upper Lias was noted by Mr. Tait at one point on the east coast of Strathaird beneath the shingle of the beach, while he was collecting from the lowest beds of the Inferior Oolite. It contains abundant Ammonites of the *Communis* and *Serpentinus* groups.

INFERIOR OOLITE.

Isle of Skye.—In the Sconser district (1) a massive strip of white sandstone is seen at intervals on the north shore of Loch Sligachan. Below Torr Mor it passes up into shaly sandstone and sandy micaceous shale with a bed of impure graphite above. As no fossils were procured Mr. Wedd is unable to say to what part of the Oolitic series the beds belong, as they are completely isolated and no great thickness is seen. In the district of Strollamus (2) very thick metamorphosed white sandstones, laminated in the lower part, form the coast and eastern slopes of Glas Bheinn Bheag. Calcareous doggers occur and seem to contain obscure belemnites. In the upper part are one or two beds of shale and of

Digitized by Google

Mr. Wedd. highly calcareous sandstone or sandy limestone altered to sandy marble. A comparison of the whole sequence at Strollamus together with evidence from the sandstone itself and from the fossils of the overlying series, clearly shows that these metamorphosed sandstones are the Inferior Oolite of Strathaird. The intrusion of the granophyre mass of Beinn na Cro and Glas Bheinn Bheag reverses the dip in anticlinal form between the two localities. In Strathaird a thick series of sandstones, more or less calcareous, white at the surface but blue when fresh, and often passing in the lower parts into beds of gritty blue limestone, forms the whole of the eastern side of the peninsula. Beds of *Avicula*, *Pecten*, *Terebratula* and *Rhynchonella* occur at several horizons. As these beds overlie the Upper Lias and pass up into the Great Estuarine series, they clearly comprise the Inferior Oolite, but whether they include any higher horizon or not depends upon whether the lower part of the Great Estuarine series is strictly homotaxial or not with the Great Oolite. A bed of black pyritous shale of variable thickness separates some 30 or 40 feet of white sandstone at the top from the sandstones below. The shale is marine and contains locally, badly preserved impressions of ammonites, but no clearly determinable specimen has been obtained. The Inferior Oolite sandstones can be recognised in a highly metamorphosed state on the east flank of Sgurr nan Each near the head of Loch Slapin.

GREAT OOLITE (*Loch Staffin Series*).

Isle of Skye.—At Strollamus (2) the thick sandstones are succeeded by a series of shales and sandy limestones; both are often crowded with small bivalves (*Cyrena ?*). Beds of dwarf oysters also occur, resembling *Ostrea hebridica*. The series is comparable in its main features with the Great Oolite of Strathaird. In Strathaird (3) the Great Oolite consists of a thick series of—

g. Blue shales and mudstones, with calcareous concretions.

f. Smooth, muddy blue limestones, weathering buff, with beds of *Paludina scotica*, intercalated shales and bands of "beef."

e. Shales with small lamellibranchs (*Cyrena ?*).

d. Calcareous shales or shaly limestones crowded with *Ostrea hebridica*.

c. Black shales.

b. Blue sandy limestones full of small lamellibranchs (*Cyrena ?*).

a. Black laminated shales crowded with the same bivalves (*Cyrena ?*).

The series undoubtedly belongs to the Great Estuarine series. The lower part, with the oyster beds, is recognisable in a metamorphosed state on the east flank of Sgurr nan Each and above the west side of the south end of Strath Mor.

OXFORDIAN.

At Strollamus (2) the shales with limestones are succeeded by marine shales with cordate ammonites; these shales must consequently be assigned to the Oxford Clay. On the

Digitized by Google

opposite coast of Scalpay, in the valley of Allt Stapaig, the following sequence is seen, the beds dipping E.S.E. or S.E. as at Strollamus:— Mr. Wedd.

		Feet.
Cretaceous	Metamorphosed cherts (?) sandstone passing under lava.	
	Metamorphosed blue limestone with cherts (?) - about	8
	Blue pebbly calcareous grit with *Pecten asper* and *Exogyra* cf. *conica* - - - - - - - - - - -	2
	Gap of a few feet.	
Oxfordian (?). or Kimeridgian (?)	Black laminated shales with indeterminable ammonites and belemnites - - - - - - - - -	

The ammonites in these shales, though too obscure for definite determination, on the whole somewhat suggest an Oxfordian or Kimeridgian horizon. As Oxford clay undoubtedly overlies the Great Estuarine series at Strollamus just opposite, it seems that these black shales probably belong to an Oxfordian or Kimeridgian horizon. In Strathaird (3) a thick series of grey micaceous shales, with thick calcareous-micaceous shaly sandstones in the lower part, cover the Great Oolite and underlie nearly the whole of the Tertiary lavas. At the base, a conglomerate of large round pebbles of white quartzite or metamorphosed white sandstone in a matrix of calc-shaly-mica-sandstone sometimes occurs. In the lower beds, cordate ammonites are locally abundant, together with large belemnites, *Pecten fibrosus*, occasionally a large *Gryphæa*, and much fossil wood. These beds undoubtedly belong to the Oxford clay, but as no fossils were found in the upper part, it is uncertain whether any Corallian or Kimeridgian horizon is present. At the top, in one place, a small outcrop of blue limestone was seen, gritty below, with pebbles of sandstone of local Oxfordian type.

CRETACEOUS.

Scalpay.—From the south of Scalpay (2), in the valley of Allt Stapaig, fossils from the thin grit above mentioned as overlying the black shales with ammonites were submitted to Mr. Newton and Dr. Kitchin, who at once suggested the resemblance of certain Pectens to *P. asper* of the Upper Greensand. This determination has since been confirmed: casts of an *Exogyra* seem to belong to *E. conica*, and a *Spondylus* may also be represented by casts. There is no doubt as to the Cretaceous age of these beds. The overlying blue limestone bed can be traced far inland in Scalpay, where it is pinched in between the granophyre and the Torridon Sandstone.

A similar blue limestone overlies the Oxfordian shales at Strollamus and may also be Cretaceous, but this needs confirmation. The same may be said of a bed of limestone seen in one place to overlie the Oxfordian shales of Strathaird (3).

Digitized by Google

Mr. Clough. *Isle of Skye.*—On the south coast of Skye a small patch of Mesozoic rocks emerges from beneath the plateau basalts between a quarter and half a mile of the foot of Allt nan Leac. This patch lies on the north side of the Sound of Soay and a little west of that referred to in previous years by Sir A. Geikie* and Mr. Harker.† It includes a considerable thickness of the *Gryphæa* beds of the Lias, and, above these, come red and green, apparently glauconitic sandstones, with occasional pebbles. In some sections the sandstones appear unconformable to the *Gryphæa* beds, but in others they are conformable. In the best section they appear to be conformable, they are about fifty feet thick, and are overlain by a chert-grit horizon, about three feet thick, in which are thin courses and lenticles of chert embedded in a gritty rock. When examined with a hand lens the chert shows many spicules and other remains of micro-organisms. Above the chert-grit horizon come two or three feet of shale with small lumps of dark chert.

In one place near the exposures of chert *in situ* there is an agglomerate which probably belongs to a small volcanic vent older than the plateau basalts. In the agglomerate there are many lumps of chert like that *in situ*, and containing similar spicules and micro-organisms. There are also many pieces of chert (?) with red cores.

Mr. E. T. Newton has examined thin slices of the cherts from the beds *in situ* and also those in the agglomerate, and he finds them very similar. The organic remains are much obscured by chalcedonic deposits, but it is clear that besides the abundant sponge spicules, foraminifera are present, both Textularian forms and others, including *Globigerina* (?). Some of the specimens also show fragments of echinoderm plates and serpula tubes. Mr. Newton considers there is little room for doubt that the cherts are of Cretaceous age, and that they have a closer resemblance to Greensand chert than to those discovered in Arran.‡

Dr. G. J. Hinde has also examined the specimens and agrees with Mr. Newton's views.

The nearest rocks of Cretaceous age that are at present known occur under the plateau basalts of Morven and Mull, at distances of forty and fifty miles.

Mr. Wedd. *Geological Structure of the Secondary Rocks of Skye.*—The above rocks seem to be arranged as follows:—Near Sconser (1) the strata are thrown into an anticlinal fold with axis running E.N.E. It is intersected by numerous faults generally with north-west direction and north-east downthrow. At Strollamus (2) the lower beds have a general E.S.E. dip from off the granophyre of Glas Bheinn Bheag, and their general dip is maintained throughout the local Jurassic series; several faults occur, but their position is often conjectural owing

* *Summary of Progress* for 1898, p. 137.
† *Summary of Progress* for 1899, p. 142.
‡ *Summary of Progress* for 1900, pp. 123, 169.

Digitized by Google

to the presence of much drift. In Strathaird (3) the Jurassic rocks are almost free from faults, except in the north, where there is much faulting. On the west side of the peninsula an important fault runs from the east side of the Camas Fhionnairaidh N.N.E. up the valley of Abhainn nan Leac. It throws down Great Oolite on the east against Torridon rocks and overlying Lias on the west. It is evidently pre-Tertiary and post-Jurassic. East of it, throughout Strathaird (3) the Tertiary lavas rest on Oxford clay or slightly overlap on to the Great Oolite, while west of the fault the lava lies on Lower Lias or Torridon Sandstone. The fault has considerable stratigraphical significance, for throughout the south of Skye, its line of continuation to the N.N.E. marks the re-appearance of Trias and Lower Lias on the west. This fault truncates the western side of a shallow syncline, which occupies the greater part of Strathaird. West of the fault a narrow anticline runs along the west flank of the valley of Abhuinn nan Leac and further north along the east flank of Sgurr nan Each and beyond it. West of the anticline another syncline is shown in the Lias of Blath Bheinn. Between Loch Slapin and Loch Eishort the Trias and Lower Lias lie in a gentle syncline. Mr. Wedd.

TERTIARY.

Igneous Rocks of Skye.—Mr. Harker was occupied during the field-season chiefly in mapping the basaltic plateaux on the west side of the Isle of Skye, between Loch Bracadale and Loch Brittle (Sheet 70, one inch). The area surveyed during the year on the western side of Skye forms part of an extensive region, throughout which like physical conditions rule. This region consists of an assemblage of deeply eroded plateaux carved out of the Tertiary basaltic group, which is a succession of basic lavas alternating with basic sills. It is thus a country of strong relief, but with extremely little variety of lithological characters. The climatic conditions, determined by the situation and the prevailing winds, are also strongly marked. The precipitation is very heavy, and storms are frequent, but the winter temperature is not severe. Mr. Harker.

Except where escarpments or crags of the more resistant rocks break through, the surface of the country is in general covered more or less thickly with peat. This covering has in great measure protected the subjacent rocks, which had previously been stripped and scoured by the ice of the glacial period, and it results that over most of the country, soil and subsoil are alike wanting. This moorland ground is given over to sheep-farming, and affords good pasturage. The slopes are roughly drained by surface cuts, where the shape of the ground is favourable, but the more level stretches, which form the flat watersheds and border the principal streams, are in the condition of bog. The peat is cut for fuel, but at present only by the crofters for their own needs. Reclamation has never been attempted except on a very small scale, and there is little prospect of any successful effort in this direction.

Digitized by Google

Mr. Harker. Cultivation of any kind is practicable only on certain narrow strips of the lower ground. On the slopes of some parts of the main valleys, and also sometimes of the narrower sea-lochs, which are submerged valleys, the boulder-clay attains some thickness, and comes to consist of a reddish loam, or sandy clay, representing the waste of the basaltic rocks. Most of the crofts occupy these situations, while others are placed on the relics of raised beaches which fringe some sheltered portions of the coast. Potatoes and oats are raised; the latter a scanty crop, which ripens late, or in some years not at all. The small size of some of the crofts, and the inequalities of the surface, render the use of horses for ploughing difficult in many cases, and the ancient *caschrom* or foot-plough may still be seen at work in the more remote places. The manure in general use is sea-weed. Owing to the heavy annual rainfall in this region the soil speedily becomes robbed of its more soluble constituents, and in any attempt at cultivation of a systematic kind, the choice of suitable fertilisers would be a prime condition of success.

Here, as elsewhere, the volcanic group is found to consist of numerous alternations of basic lavas and intrusive sills, also of basic composition. The lavas present somewhat more variety than in the districts formerly mapped. The amygdules in them sometimes attain a large size, and contain a profusion of zeolitic minerals, often very perfectly crystallized. Another interesting feature is the not infrequent occurrence of bands of red clay (plinthite) due to the surface of a lava-flow having suffered subaërial weathering before it was covered by the next succeeding flow. Only rarely is the monotony of the succession broken by lenticular patches of volcanic agglomerate, indicating the neighbourhood of small vents now concealed. In one coast-section, near Dùnan Earr an Sgùirr, occurs a fluviatile deposit, some thirty feet in thickness, marking part of the course of one of the rivers of the volcanic epoch, and consisting of alternations of conglomerate and bedded tuff. The pebbles are of granite and Torridonian grit, rocks nowhere exposed in this part of Skye.

The regularly stratiform intrusive sills of dolerite intercalated among the lavas make up more than half of the total thickness, and, owing to their superior durability, form all the prominent features of the landscape. They have in this district a very general vertical prismatic jointing. In particular, the isolated hills Preshal More and Preshal Beg, near Talisker, afford a magnificent display of regular columnar structure.

The great majority of the sills are not porphyritic in the ordinary sense, but some enclose sparingly scattered crystals of felspar of conspicuous dimensions. One sill of peculiar character is well exhibited in a small isolated hill (crowned by a Dùn) about two miles north of Talisker. It is about 100 feet thick, and the upper and principal portion is crowded with large porphyritic felspars, but lower down these become rarer, and at the base they disappear entirely, while the rock assumes in other respects a different character. A comparison is suggested with certain

Digitized by Google

composite double sills formerly noted on Roineval and elsewhere; but in the present instance there is no sharp dividing line between the upper and lower portions of the sill.

Mr. Clough. While mapping the small area of Liassic and Cretaceous strata already referred to (*ante* page 146) as occurring on the north side of Soay Sound, Mr. Clough found an agglomerate with fragments of chert, containing sponge spicules and micro-organisms similar to that found *in situ*, near at hand, and which Mr. Newton considers to be probably of Greensand age. Mr. Clough is of opinion that the agglomerate "belongs to a small vent older than the plateau basalt." In addition to the fossiliferous cherts, the agglomerate contains many pieces of chert with red cores, the exact nature of which is doubtful.

Island of Soay.—The intrusive rocks in the Island of Soay are regarded by Mr. Clough as of Tertiary age. Perhaps the earliest intrusion is the small elongated mass with flattish top which forms Dubh Sgeir, which is a peridotite. It is in part crowded with inclusions of troctolite, some as much as 18 inches long, and is crossed by two N.N.W. dykes.

The other intrusions form dykes, running N.W. or N.N.W. as a rule, or sills. Many of the dykes and sills are rich in olivine, and some of the sills consist of dunite or picrite. These highly basic rocks frequently cut others of dolerite or basalt.

There are a number of sills of porphyritic basalt, and in these the felspar phenocrysts near the centre are often two or three inches long, and one or two broad. Rarely they are as much as eight inches long, and four broad. These phenocrysts invariably diminish in size near the margins of the sill, and for three or four inches next the selvage they usually disappear. This seems to indicate that the phenocrysts are not strangers in the rock, but have been developed *in situ*. Similar phenomena are observed on the course of a long dyke of porphyritic basalt which crosses the E. side of the island in a nearly N. direction.

Near several of the intrusions the Torridonian grits have been partially vitrified into buchite.

Messrs. Peach, Wilson, and Muff. *Inverness-shire and Argyleshire.*—Dykes with a general N.W. and S.E. trend are more or less numerous in all the areas mapped in this region during the season. These vary from highly basic olivine basalts to trachytes and even rhyolites. As they traverse all the rocks, as well as most of the structures above described they are considered to be of Tertiary age.

A few basalt or dolerite dykes of this age were met with by Mr. Wilson in the area mapped by him north of the Great Glen.

Mr. Muff traced dykes of two types, viz:—dolerites and hornblende-andesites, across the northern end of the island of Lismore. The relative dates of intrusion of these two types is doubtful, but Mr. Muff formed the impression that at least one of the andesite dykes traversed a dolerite dyke.

In the district south of Oban (Sheet 45) dykes of this age become more numerous. East of Kilbride they all appear to be basic in composition; but to the south of Loch Feochan there is

Digitized by Google

Messrs. Peach, Wilson and Muff

a belt of country about a mile wide where compound dykes occur, in which successive rocks of increasing acidity from olivine basalt up to rhyolites have welled up one and the same fissure. Several of the fissures can be shown to have been used as an escape for gases after they had been filled by one or more of the earlier molten intrusions, as they are partially filled with agglomerate and tuff made up of thin fragments of these rocks as well as those of the walls of the fissure, and through this agglomerate some of the more acid rhyolites can be seen to have risen. A very good example of such a dyke is exposed within a few yards of the road along the south shore of Loch Feochan, about one-third of a mile from its head. The oldest rock filling the fissure is an olivine basalt. This is pierced by a massive dolerite dyke which exhibits chilled edges against the basalt. The dolerite and the basalt are traversed by fissures filled in with agglomerate of their fragments and lastly a dyke of rhyolite with double pyramids of quartz and showing fine fluxion structure along its edges, cuts both the basalt and the agglomerate.

One of these compound dykes, stretching from the head of Loch Feochan to near the head of Loch Scamadale and extending further south with the same trend, swells out at irregular intervals into a succession of wide internodes partly filled with fragmental and partly with molten materials, which evidently represent a series of volcanic vents arranged along the line of fissure. One of these vents was observed by Mr. Symes and reported on previously. (*Summary of Progress* for 1898, pp. 153, 154.)

In several instances the trachytes and rhyolites form simple dykes which traverse the andesite lavas of Lower Old Red Age, which form the "rocks of the country." In others these acid dykes are seen to converge with basic ones and unite to form compound dykes like those described above.

Mr. Kynaston

In the south-western portion of Sheet 45 the Lower Old Red lavas are intersected by numerous Tertiary dykes, mostly with the direction N.W. and S. E. The larger proportion of these belong to the dolerites and basalts, while along a certain zone a set of acid dykes have also been mapped. The basic intrusions are exceedingly numerous and vary greatly in breadth. The breadth, too, of an individual dyke often varies considerably, and their course may be sometimes diverted from the normal along older lines of faulting. Petrologically the rocks vary from a medium-grained dolerite to olivine basalt, or tachylite in thin bands. In some places a more felspathic type of dyke occurs, suggesting affinities to an intermediate type, such as trachyte. Compound dykes, consisting of two or three varieties of intrusion, running side by side in the same fissure, are common.

The acid dykes are well seen in the Loch Scamadale area. They are mostly pale grey felsites or rhyolites, occasionally with porphyritic quartz and felspar, but often too decomposed for satisfactory examination. They exhibit a well-marked flow structure, and often break up, on weathering, like a mass of slate, parallel to the wall of the dyke. They frequently split up the

Digitized by Google

basic dykes, or form compound dykes along with them. A well-marked line of such compound intrusions runs along the course of the Braglenmore burn, south-east of the head of Loch Scamadale, and is continued to the north-west in the direction of Kilmore in Glenfeochan. (*Ante* p. 150.) Along this line a feature of special interest is the frequent occurrence of masses of ash and agglomerate, consisting of fragments of basalt, felsite, and andesite, evidently indicating a line of volcanic vents of an explosive type. The ashy material occurs in roughly oval-shaped masses, breaking through the andesites, or as bands bordering the acid dykes. Occasionally the ash is seen to be cut by the acid intrusions. Mr. Kynaston

Kilmartin District.

Kilmartin District.—In Kilmartin district, lying between Loch Avich and Loch Crinan, mapped by Messrs. Peach, Wilson and Muff, during the season, basic dykes of this age with a generally N.W. and S.E. trend are extremely numerous. In the northern half of the area as many as thirty may be crossed in a traverse of a mile in aN.E. and S.W. direction. They vary in thickness from several yards to a foot or so, and in texture and composition from coarse-grained olivine-dolerites to fine-grained rocks, which probably include andesites. Some of the more basic varieties show tachylite margins, and some are vitreous throughout. Many of the more andesite-like dykes have glassy cores, with a more or less broad selvage of rocky texture; but a few are glassy throughout. That they are not all of one and the same date of intrusion is shown by the fact that at Port an Deora, a little to the N.W. of Duntroon Old Castle, Mr. Wilson observed a N.W. dyke which cuts through another dyke of coarse dolerite which, in this part of its course, trends nearly E. and W., the later dyke showing chilled edges against the dolerite. Compound dykes also occur. Messrs. Peach, Wilson and Muff.

Mr. Muff observed one of the less basic dykes to converge with a dolerite dyke and run beside it for some distance within the one fissure without crossing the latter. Two compound dykes were traced by Mr. Wilson inwards from near the head of Loch Craignish, one through Loch Fearphuirn and the other through Strome, which are believed by him to be the continuation of two dykes mentioned in last year's *Summary* by Mr. Symes as crossing the Craignish Peninsula on the other side of the loch.*

Alteration produced by the Tertiary Intrusive rocks in Skye.—Mr. Harker has supplied an account of the dedolomitization of the Cambrian dolomites of the Strath district of Skye by the Tertiary Plutonic masses. (*Ante* p. 131.) Mr. Harker.

Mr. Barrow also furnishes an interesting account of the effects of the Tertiary dykes upon the clastic mica flakes in the Lias clays of the Heast district. Mr. Barrow.

---

* *Summary of Progress* for 1900, p. 127.

Digitized by Google

Mr. Barrow. The Lias shales of Skye, like those of Yorkshire, contain numerous large flakes of mica. They are so much cut up by dolerite dykes that it interferes with the mapping of the area. The effect upon the micas in the shales, close to their contact, is similar to that produced upon the micas of the Yorkshire Lias by the Cleveland dyke, only, in the present case, a dyke 10 yards across destroys the micas for at least 6 inches from its edge, which is more than that produced by the Cleveland dyke where it is 50 yards wide. This greater alteration may be due to the igneous material being nearer its source of origin and so having a higher initial temperature; or it may be due to the fact that the intrusions were so numerous as to heat the Lias more than we suppose, and so leaving less work for each particular intrusion to do. It should be recognised that these shales may be raised to a high temperature without leaving any evidence that they have been so. Mr. Maynard Hutchings has proved by experiment that a moist clay, enclosed in a steel cylinder, may be kept at a dull red heat for weeks without the slightest sign of alteration being produced on it that can be recognised, even by the aid of a microscope. The lithology of the lowest beds of the Lias promises to be more than usually interesting; and the alteration of these beds by small intrusions seems to be equally so. A large number of specimens have consequently been collected to investigate these points as soon as time permits.

Mr. Clough. Mr. Clough observed that the Torridonian arkoses in the Island of Soay were glazed and altered along the margin of the Tertiary dykes and intrusive sills producing Buchite. Similar phenomena occur in Applecross and Islay where Torridonian arkoses are traversed by Tertiary basic dykes.

Pleistocene, including Glaciation and Glacial deposits.

Island of Soay.—In the Island of Soay there are no widespread drift deposits, but scattered boulders of rocks, chiefly freestone, granophyre and gabbro, foreign to the island, are common. There are also rare boulders of mica-schist and hornblendic gneiss. Glacial striæ are numerous, and most of them run nearly E. and W. The N.E. corner of the island, near Clachan Uaine, has been invaded for a little distance by a drift almost entirely composed of blocks, often of very large size, of gabbro and troctolite. These blocks must have travelled from the Cuillin Hills of Skye, and perhaps they were carried to their present position after the ice from the mainland of Inverness-shire had dwindled to such an extent that it no longer reached Skye.

Mr. Wilson. *Glen Nevis.*—In Glen Nevis, Mr. Wilson obtained evidence as to the amount of drift deposits which must have been removed by denudation since the later phases of the glaciation of this region. A series of pot-holes were observed on the steep glaciated cliffs that bound the gorge made by the River Nevis at a point a mile below Steall, and a short distance beyond the point to which the coaches

Digitized by Google

run. The highest of these is 275 feet above the present level of the river. Their mode of occurrence is such that they could have been only produced by the river when it flowed at higher levels, and Mr. Wilson is of opinion that a barrier of morainic *débris* must have formed an obstruction across the gorge at this point which has been removed since glacial times, and that the pot-holes show successive stages on the removal of the *débris*. There is also evidence that the upper part of the glen was occupied by a loch which has been drained by the removal of this barrier, and which is now represented in the wider valley above, the bottom of which is filled in with alluvial terraces. Mr. Wilson.

Lismore.—The drift on the Island of Lismore is represented by a tough boulder-clay containing scattered stones, many of which must have been derived from the mainland. The matrix of the clay at the north end of the island is somewhat reddish, whilst towards the south-west part of the area it becomes quite black. The change appears to be gradual, and is doubtless due to the grinding up of the limestone and its incorporation in the clay during the south-west movement of the ice. The percentage of limestone boulders in the clay also increases towards the south-west. Amongst the boulders from the mainland the following have been identified by Mr. Peach :—Quartzite, porphyrite (probably of Old Red Sandstone age), Old Red Sandstone arkose (from the Great Glen), many varieties of granite, including some traversed by pegmatite veins, from the north side of the Great Glen, and also the basic edge of the Cruachan mass, Moine schist, and an agglomerate like that of Ben Nevis. The boulder-clay forms a few mounds situated on the lower ground or banked against steep limestone scarps. Two winding kames, situated half-a-mile south-west of Port Ramsay, run across the low ground in a south-east direction. Mr. Muff.

Large boulders of granite and quartzite are scattered over the hills at all altitudes. Some lie against a pedestal of limestone, which they doubtless formerly capped.

The direction taken by the striæ is very variable, but is, on the whole, about parallel to the long axis of the island, and the striæ indicate a south-westerly movement of the ice. On a small island west of Eilean Ramsay a set of striæ, running from N. 5° E., is crossed by a later set running from N. 70° E. The striæ are preserved only on the igneous rocks, and then almost always between tide marks. Some idea of the rate of the atmospheric denudation of the limestones may be gained from the fact that at low water mark the limestone is nearly flush with the striated surface of a dyke, whilst at about high water mark the striated surface on the dyke stands about one foot above the surface of the limestone. This denudation must have taken place, if not since the epoch of the 25-feet beach, at any rate since that of the 50-feet beach.

Region south of Oban.—In the area near Kilmore, mapped by Mr. Peach during the season, the glacial phenomena are almost entirely attributable to the later glaciation. The striæ show a general ice movement across the country from E. to W. On the high plateau between Loch Nell and the Feochan Beg, Mr. Peach.

Digitized by Google

Mr. Peach.

the striæ trend a little to the north of west, while those found in the valleys have a tendency more or less to conform to the direction of the valleys. Moraines made up in great part of schistose rocks, and granite from the Cruachan region are scattered over the plateau independently of the present valley system in such a manner as to show that the glaciers after leaving the Highlands must have coalesced and over-ridden this part of the surrounding lower ground. Loch Nell seems to have been the site of a tongue of this ice during the 100-feet beach time, as moraines are found on the terrace of the 100-feet beach which forms its present dam. Another tongue of the ice must have occupied the Feochan Beg as far down as Craigentaggart during, or since the 100-feet beach time, as moraines are found in the bottom of the valley above, which at this point is below the 100-feet level, while further down the river has cut its terraces of alluvium through the 100-feet and 50-feet beaches.

Trains of boulders are common across the area in the same general direction as the striæ. Thus north of Loch Nell there is a wide train of boulder of Cruachan granite; but perhaps one of the most striking trains of boulders is that supplied by an exposed portion of a large porphyrite dyke occurring on the hill top to the south of Glenamacrie, in Glen Lonan, from which a very conspicuous train of boulders can be traced to Torran Tuirc, near the head of Loch Nell.

Messrs. Peach, Wilson and Muff.

Kilmartin District of Argyllshire.—In the narrow belt of ground mapped in this region during the season, stretching from Loch Avich in the north to the Crinan Sea Loch on the south, the rock is singularly bare of drift. The ice-movement over the area, as indicated by the striæ and the carry of blocks, was towards the W.S.W., with local deviations according to the shape of the ground.

The sparse glacial deposits are mostly of a morainic character, but Mr. Muff mapped some small areas in the neighbourhood of Salachary of what may be looked on as Boulder Clay. With perhaps this exception, most of the phenomena observed are attributable to the Later Glaciation, when the glaciers from the higher Highland valleys to the head of Loch Awe coalesced on the low ground and overrid the lower plateau of which the present is a portion. Moraines are common to the south of Loch Avich, on the water-shed between Glen Domhainn and Loch Awe, where they could not be laid down by local glaciers nursed within the water-shed. Boulders, foreign to the region, such as granite and schist, like those surrounding the Cruachan massif, are scattered over the area. Boulders of andesite and porphyrite like those which traverse the andesite rocks north of Loch Awe are abundant within the area.

As probably showing a stage in the shrinking of this confluent glacier, a lake terrace 200 feet above the present level of the loch is found round the S.W. or upper end of Loch Avich, of such a character and in such a position that it must have been formed when the lake drained to the S.W. into Glen Domhainn, the head of the Barbreck River. The gravels and sands of this

Digitized by Google

terrace have been traced to the actual water-shed at about one-third of a mile to the S.W. of Maolachy on the road between Kilmelfort and Loch Avich, where the road traverses a small rocky gorge evidently cut by the water flowing out of the lake. The fine silts and sands of the terrace can also be seen near the roadside near the same spot. The present outlet of the lake shows no evidence of a barrier of moraine stuff or rock of such depth having been removed since glacial times, and the only explanation of the high terrace, which is in every way comparable to one of the terraces of the "Parallel Roads of Glen Roy," is that the barrier was due to the lower end of the lake being occupied by ice when the terrace was formed. Messrs. Peach, Wilson and Muff.

Island of Soay.—As might be expected from the exposed position of the Island of Soay, the material in the raised beaches is very coarse. To a large extent it is composed of boulders two or three feet long, which have been piled up in storm banks. There are small deposits of gravel as much as 60 feet high, but perhaps these were thrown up in storms considerably above the general sea-level. Mr. Clough.

Lismore.—The north coast of Lismore bears a well marked terrace at an altitude of about 35 feet above O.D., which doubtless corresponds to the 50-feet beach of neighbouring areas. Though usually a bare rock ledge, it is sometimes covered by water-worn gravel, containing similar rocks to those found in the Boulder Clay, in addition to many limestone pebbles. No shells have been obtained from this deposit. Undisturbed Boulder Clay reaches down to this beach, and no evidence of a higher beach was obtained. The cliffs bounding the 50-feet beach are indented by many small caves, whose walls are covered by stalactites. At Sron-na-bravibhe, in place of the cliffs there is found a curved ridge of gravel, concave towards the sea, and formed of false bedded ferruginous sand and gravel of essentially the same composition as that found on the 50-feet beach elsewhere. This ridge in cross section has a long gentle slope seawards, and a short steep slope on the landward side, where the surface drainage is obstructed and a peat moss has formed. Similar though smaller ridges, are found in analogous positions to the north and to the south of Port Ramsay. They appear to be storm beaches of the 50-feet beach period, behind which shallow lagoons may have existed at that epoch. Mr. Muff.

A lower raised beach, which is distinguished only with difficulty from a more modern storm beach, appears to be preserved only near Port Ramsay, where the coast is sheltered by small islands. Peat, besides filling shallow depressions of the Boulder Clay surface and lying behind the old storm beaches already described, occupies the site of former lochs, at the source of Allt a'Mhuilinn and again just south of the school house.

Lorne District.—Near Kilmore the 100-feet raised beach occupies a well-marked terrace at the foot of Loch Nell and in the angle between the Feochan Mor and Feochan Beg rivers. The terrace, partly as a rock notch and partly covered with beach Mr. Peach.

Digitized by Google

Mr. Peach. materials, can be traced down the south-east side of Loch Feochan for some distance from its head.

The 50-feet beach is also well displayed in the same district. At Kilmore it is much covered by a coating of peat. It can be easily followed down the south-east coast of Loch Feochan close to the high road, and the rock caves along its margin are still often tenanted by tinkers and tramps who contribute the refuse of the shellfish they use as food to the kitchen middens found at their mouths.

Mr. Wilson. *Kilmartin District.*—The 50 feet beach is well marked along the seaboard from Crinan Loch to the head of Loch Craignish and also to Island Macaskan and Eilean Righ. It extends up the Kilmartin Valley to within a mile of the village, and on it rests the extensive peat-mosses of Moine Mhor and Poltalloch. This terrace is generally composed of rolled stones and gravel, and a section on the River Add, near Drumore, shows ten feet of fine horizontally-bedded gravel on top of stiff, light grey Boulder Clay.

On the east side of Loch Craignish and the two islands, the 100-feet beach is not well marked, but in the Kilmartin valley on both sides it forms a conspicuous feature, and extends as far up as the cross roads to Ford and Oban. A short distance to the west of Eurach a belt of epidiorite lies just beyond the upper limit of this beach and extends across the valley. This band has numerous pot holes, which must have been formed during the 100-feet beach period, and when the surplus water of Loch Awe passed down the Eurach valley. At Slockavullin and near Balameanoch, clay pits have been wrought in this beach deposit and a fair quality of bricks and tiles produced.

Messrs. Muff, Peach, and Wilson. *Economic Minerals.*—The largest area of limestone is to be found in Lismore. At present it is only burnt at Port Ramsay, whence it is taken away in boats, and there is an annual output of about 600 tons; but the supply is practically inexhaustible. Limestone has been more or less locally wrought and burnt all over the Kilmartin area, but at present it is evidently cheaper to import lime from Lismore and other places than to produce it on the spot.

The epidiorite sills afford the best building stone in the Kilmartin region. Any granite used in this part of the country is obtained from boulders. The limestone and quartzite are used considerably for drystone dyke building.

Road metal is everywhere easily procurable and of excellent quality, owing to the innumerable basalt and dolerite dykes that traverse the region The little dark limestone that is found in the black schist, especially where it has been slightly altered, near one of the basalt dykes, also affords good road metal.

A brick clay was formerly used at Slockavullin, one mile south-east of Kilmartin. It appears to have originated from the alluvium of the Slockavullin stream, where it has been dammed back by a spit of the 100-feet beach. The clay appears to be exhausted or no longer workable.

Digitized by Google

In this district the Moine Mhor and Poltalloch peat mosses afford an almost inexhaustible supply of fuel. Some years ago Lord Malcolm of Poltalloch erected plant for converting the raw peat into peat coke. The machinery came from Sweden and the experiment was highly successful, but on account of the small size of the plant the financial results were not satisfactory. This year the machinery has been removed to the south side of the Moine Mhor, and, with additions, it is to be employed on a much larger scale in the production of coke for the iron smelting works which are being built near Island Add Bridge. Mr. Wilson.

More than a hundred years ago several small veins of copper were wrought at the top of the hill, and close to the old hill road which crosses from Kilmartin House to old Poltalloch. The veins intersect the large epidiorite sill, and these have been only opened up by shallow trenches and a small water level, about twenty yards long, with connecting shaft of similar length, to the hill face above. The ore obtained was chiefly malachite with a little black oxide of copper and manganese. The leading vein is about four feet in breadth and the walls are lined with calcite and quartz crystals. The vein face at the end of the water level is cemented up with stalactitic material and quite concealed.

3.—East Highland District.

Dr. J. Horne, F.R.S., District-Geologist (acting).
Mr. G. Barrow,
Mr. E. H. Cunningham-Craig,
Mr. J. S. G. Wilson,
} Geologists.

In the Eastern Highlands, Mr. Barrow continued field-work in the district of the Tarf Valley, in Atholl Forest, in Sheet 64 one inch; and Mr. Cunningham Craig surveyed a tract lying immediately to the north in the Glen Feshie Forest and in the neighbourhood of Newtonmore. In the autumn Mr. Barrow completed the mapping of a small unfinished area near Balmoral in Sheet 65 one inch. In connection with the publication of Sheet 55 one inch, Mr. Barrow re-examined the Garry section north of Blair Atholl; Mr. Wilson drew additional boundary lines in Strath Tummel; and Mr. Craig mapped in great detail the area extending from a line north of Pitlochry to near Blair Atholl.

Tarf District.—Mr. Barrow reports that a considerable portion of the area drained by the Tarf, on the north side of the Tilt valley, in Sheet 64, is composed of typical Moine-gneisses which, on the whole, closely resemble the gneisses of the Bynach area, described in a previous report. The tendency to local variations in the gneisses of the latter, has also been observed in the Tarf area. There are, however, some differences between the rocks of the two areas. The colour banding so common near the Bynach is not so frequently met with in the area surveyed during the past season, Mr. Barrow.

Digitized by Google

Mr. Barrow. The typical parallel structure is present over most of the area, but it is often shown more by the parallelism of the biotite than by any other feature. This local peculiarity of the gneisses is clearly connected with another which characterises parts of this district. The Moine gneisses often weather like a fine-grained granite—a feature which is not confined to a few small bands; indeed large masses of rock at a short distance off so closely resemble granite in appearance that the rocks had to be carefully examined to make sure that they were not really original igneous material intruded in a sill-like form in the Moine gneisses. It was found that in this type of rock a vast number of small patches had lost all trace of parallel structure; indeed the transition to the part of the rock showing the normal parallel arrangement of the biotite is so gradual, that a series of specimens has been collected to investigate the structure and composition of this type of material.

While over much of the district the arrangement of micas and the colour banding, when well marked, is parallel to the original bedding of the rocks from which these gneisses have been formed, there is rather a broad belt in which this is not the case. In this belt the gneisses show the typical thrust-plane structure of the Southern Highland grits. These thrust-planes cut the rocks intersected by them into thin phacoids in which the relation of the main axis of deformation to that of the least is largely determined by the fineness or coarseness of grain of the sandstone or grit before deformation. A grit is cut into much shorter and thicker lenticles than a fine green sandstone or greywacke; and from the tenuity of the phacoids in these Moine gneisses we at once know that they were originally very fine grained rocks, containing a considerable amount of chloritic material. The cause of this deformation has been well established. It is connected with the trend of the dyke-like intrusions that supplies the material of the sills of epidiorite in the Southern Highlands.

While the bulk of the Moine gneisses must have been originally very fine sandstones, here and there this material was replaced by what was originally more of the nature of a shale. Though now altered to an oligoclase-biotite gneiss, there is no doubt that it was originally a shale, for it still retains the minute puckering which is distinctive of altered shales as opposed to sandstones, which never show this feature except at their junction with a softer rock.

A special feature of the Tarf area is the frequency with which the junction of the gneisses with the Central Highland quartzite can be observed, and as a rule there is a very gradual passage from one rock to the other. Still more important, however, is the clear evidence that the whole of the Moine gneisses in the region examined by Mr. Barrow lie between the quartzite on the one hand and the Little Limestone (Tremolite limestone of Braemar) on the other. They are, in fact, only a small zone in the Highland rocks.

Digitized by Google

Mr. Barrow.

The details of the evidence in the Tarf area are complicated by the interruptions due to the great intrusions of Newer Granite in the district, but there can be no doubt that these gneisses do lie between the two rocks named above.

This conclusion is further strengthened by the evidence in the Falar area, which may here be described.

In Glen Mhor, a little below the junction with Glen Bheag, a remarkable group of rocks is seen which have been called "honestones," as they were for many years used as hones, and people came to this locality from great distances to get them. Similar rocks are known to occur at this horizon in many localities. They are clearly seen to lie between the quartzite and the Little Limestone (Tremolite limestone of Braemar). The dominant constituent of the group is a thin banded fine-grained brownish rock, essentially composed of a granular admixture of quartz and felspar, through which a considerable amount of brown mica is disseminated. The mica occurs parallel to the banding of the rocks and intensifies the evenly bedded aspect of these "honestones." The brown bands are often separated by thin partings of more micaceous material, clearly mud or shale originally, which was "cross-cleaved" prior to crystallisation: a phenomenon identical with that seen in the Silurian rocks of the north of England. The occurrence of these "cross-cleaved" bands, persistently parallel to the brown bands, is clear proof of original bedding in these crystalline rocks. In addition to these constituents, there are also a few thin bands of pink weathering granular material, and more rarely a few white layers. The composition of the latter is of importance; for while there is hardly any white mica in the brown bands, there is usually a considerable amount in the pink and white material. There is still another distinctive feature of the group. The brown beds are divided up into thin layers by extremely persistent films of what was originally chlorite, but is now more or less completely altered to a "felt" of brown mica. Thus it will be seen that these beds are a singularly well-marked group in which parallel banding is the dominant feature, and if we start from the edge of the quartzite we see at once that they are essentially a passage material between the quartzite and the dark shales, on the reverse side of the Little Limestone. These rocks, when traced, frequently undergo local changes in composition, becoming more or less siliceous, but each individual band of the whole group undergoes this change; no band is cut out and replaced by material of different composition.

In the bed of the Tilt, just below Pool Tarf, the "honestone phase" of these rocks is exceptionally well seen; but here they are slightly thicker as a whole, and this slight thickening is well shown by the cross-cleaved bands. At this point they occur exactly on the line of rapidly increasing alteration, to which attention has been drawn in former reports and which will be referred to again in the sequel. From this locality the rocks become rapidly more crystalline, and this change can be followed on bare rock onwards to Pool Tarf, and up the gorge of the Tarf,

Digitized by Google

Mr. Barrow. where they rapidly pass into the typical Moine-gneiss of the great area to the north. It is fortunate that these beds can be so quickly traced from the less altered to the far more highly crystalline condition without the intervention of any infold of other material to break the continuity of the evidence.

Bynack District.—Confirmatory evidence is obtained in the Bynack area, where the Moine gneisses have an almost identical structure and composition with that of the "honestones." The typical grey gneiss, by far the most important member of the group, contains little and often no white mica, while the pink and white bands invariably do so, as in the "honestones." The structure is essentially granular in both rocks, but the grains are much smaller in the "honestones." The biotite in both rocks has essentially the same colour, being intermediate between that of Haughtonite and the rich red contact mica.

Struan District.—The widening of the Highland Railway above Struan has exposed admirable sections of the Moine gneisses. As usual they show the parallel banding due to layers of different composition, as well as the parallel arrangement of the micas. The dominant constituent of the group is the grey well crystallised gneiss, which is associated with a subordinate amount of pink and white gneiss. In addition cross-cleaved mica gneisses are present, but these form quite a small proportion of the whole. The increased thickness of the latter when compared with the "honestones" is even more marked than in the Tarf area. The examination of the whole series of sections suggests that there is only one moderately thick bed of cross-cleaved mica gneiss, for wherever visible it is apparently always accompanied by the same grey, pink, and white bands, though there is often a certain disparity in the relative thickness of these three components. The railway sections show that though there is a steady dip in one direction, the same beds are constantly repeated. It is here seen that at short intervals the rise of the beds, owing to the persistent dip, is counteracted by a short, nearly vertical, roll over. This roll over can be made out in the river sections, but its effect in individual cases can rarely be traced with the clearness made possible by these new railway cuttings. These rocks in Glengarry have long been known as the Struan Flags from their flaggy mode of weathering —a feature which is largely due to the original presence of felted chlorite (now biotite) films, as in the "honestones." These films are often a specially marked feature of the Struan or Garry gneisses. As usual there is a considerable amount of variation in the composition of these rocks, but, broadly speaking, it is much less pronounced than in the area farther east. It may be noted that before crystallisation, the original beds in this district underwent far more mechanical deformation than in the Bynack and other areas, which has resulted in the production of a greater amount of white mica,

Digitized by Google

The further examination of the deep sections in the Falar area by Mr. Barrow has thrown much light on the other members of the succession which are there associated with the parallel banded series or Moine gneisses. Mr. Barrow.

With regard to the succession, whether ascending or descending, it is as follows, *when complete* :—

1. The altered parallel banded calcareous shales.
2. The Main Limestone.
3. The dark or leaden schist.
4. The Little Limestone (locally the Tremolite limestone).
5. The parallel banded series (hornestones, etc.).
6. The Central Highland quartzite.

(1) The altered parallel banded calcareous shales are among the most easily identified rocks in the Highlands, and are never absent, to my knowledge, from any valley between two quartzite mountains broad enough to show the whole succession. They occur at intervals from Falar to Braemar, and where some of these bands have a suitable composition they always have a peculiarly hornfelsed character. The thicker and more calcareous bands contain white pyroxene and are far more coarsely crystalline—a feature which is characteristic of the outcrops between Ben Vuroch and Braemar. Nevertheless, within certain limits, these bands vary incessantly in total chemical composition.

(2) *The Main Limestone.*—This can generally be recognised by its purity and persistent thickness. When specially siliceous, as in Glen Mhor, every member of the succession with which it is associated is more than usually siliceous, except of course the quartzite.

(3) The dark or leaden schist, which covers such large areas, varies considerably in composition in different localities. In its normal dark phase this schist may be divided into certain well-defined zones that have been traced over a large area. A little way from the edge of the Main Limestone it contains a large amount of kyanite, in regions of moderately high alteration, but this gives place to other silica aluminates, such as sillimanite, andalusite, or cordierite, in the areas of highest alteration. Nearer the Little Limestone we have the rock with felspar (or hornfels of Glen Callater), and the zone, with large plates of twin-chlorite. In many cases, these schists, originally rich in chlorite, contain a peculiar association of micas; the normal white mica does not occur in them. No part of this schist, in all this area, ever possesses the dead-black colour, accompanied by disseminated graphite that so often characterises part of the true graphite schist.

(4) *The Little Limestone.*—In tracing the changes that occur in this sedimentary series, it has been found that this limestone is altered to a Tremolite-rock only when the schist next it is dark in colour and associated with the twin-chlorite-rock and the felspar-rock. In varying phase of composition it occurs over a very large area. North of the Tilt it is usually an intensely hard, green, flinty rock, containing a very variable amount of garnet, and a smaller quantity of idocrase. The green colour is due to disseminated

Digitized by Google

Mr. Barrow. green pyroxene. In the Tilt valley it is less highly crystalline, but, being frequently exposed in the river bed, we are able to note how very variable in composition the rock is. It is doubtful if green pyroxene occurs here, but garnet and a little idocrase are sometimes found. In the Glen Mhor area it is usually a rather siliceous limestone, with lenticular siliceous ribs, somewhat resembling those seen at one locality in the Main Limestone. In this phase the Little Limestone occurs in a great number of places, but, previously, it was regarded as the base of the Main Limestone, caught in a fold. On this supposition the structure of the ground was difficult to understand, but the map is at once rendered intelligible when we know that there are two limestones, and not one. About four miles south of Braemar this bed again occurs, where it contains numerous garnets, but no pyroxene. About the north side of the Dee it re-appears as a green, flinty rock where next the parallel banded series. Again, east of Balmoral, the same flinty green rock, with garnet and a little idocrase, is seen, but nearer Badvo the green portion is a mere film, and the main part of the rock is now built up of radiating spherical masses of Tremolite, associated with some calcite and a micaceous mineral. Throughout its whole course it shows liability to change in chemical composition, like the parallel banded series.

(5) The parallel banded series has already been sufficiently described, but the zone shows better than any other the fact that these rocks, while incessantly changing, also incessantly revert to the normal type. Thus the flaggy hornfels of Glen Callater is the flaggy hornfels of Glen Fender, near the mouth of Glen Tilt, and the hard, parallel banded biotite schist next the Little Limestone in Glen Mhor was obviously the same material, originally, as the hard, banded biotite schist to the east of Balmoral.

(6) *The Central Highland Quartzite.*—This zone furnishes remarkable evidence bearing on the original thickness of the Highland series. The succession is as follows:—

(*a*) The fine white edge of the quartzite.
(*b*) The quartzite banded by fine lines of heavy minerals.
(*c*) The porous quartzite.

The porous quartzite, which is between six and eight feet from the fine white edge of the mass, is very easily recognised from the holes left in it owing to the decomposition of rather large and scattered felspar pebbles. (The remnants of these in the holes were clearly seen both by Mr. Horne and myself.) Now this band, according to Mr. Barrow's observations, runs through almost every great quartzite mountain, and the evidence suggests that these three zones together form the greater part of the original mass. Ben y Ghloe is formed of quartzite, folded on itself to the exclusion of every other rock. The folds in this mountain are 2,400 feet deep at least, and there is not a bend or buckle in the folds, while the bedding planes and limbs of the folds have a persistent dip of 60° for nearly two miles. The porous quartzite occurs repeatedly in this mountain, as it does again in another huge mass of quartzite seen in Cairn Righ, farther east. As

Digitized by Google

already stated, its mode of occurrence is such as to suggest that there is probably not much more than the three bands, a, b, and c, present, and we are led to the conclusion that these enormous masses of quartzite are built up by the isoclinal folding of a bed that may be not more than twenty or thirty feet thick originally. Mr. Barrow.

At intervals, across the whole area known to Mr. Barrow, parts of the series are missing. This is clearly shown when the Main Limestone is in contact with the quartzite. The phenomenon suggests that we are dealing either with non-deposition, due to current action, or with local erosion, equally due to current action. The probability is that in such a series we are dealing with both, and the mode of occurrence of the "Boulder-bed" is strongly suggestive of local erosion.

The further result of the work in this district shows that a line or belt of rapidly increasing alteration can be traced from the upper part of the Dee to a point a little north of Blair Athol. This belt passes through the great mass of basic diorite in Glen Tilt, without being the least affected by that intrusion; and the line can again be shown to be independent of Newer Granite intrusions, as proved in the Bynack area, where the Newer Granite is comparatively rare. From Braemar a similar line roughly corresponding with the Dee can be traced for about four miles down the river. It has been shown by the rock sections that the increase in crystallisation to the N. of this line becomes less and less marked, till in the area east of Balmoral it is very slight and extremely gradual. This progressive metamorphism is intimately connected with the problem of the widespread hornfels type of alteration which will now be described.

The evidence on this interesting question now points clearly to a definite cause for this alteration. This type has been found in the Falar and other areas, where the metamorphism cannot be attributed to Newer Granite alteration. It occurs repeatedly between Ben Vuroch and Braemar; and is mainly confined, when well shown, to two beds. The first of these is the banded calcareous shale next the Main Limestone. In this, as already stated, the bands are almost glassy at times, and the constituent grains are there very small.

The other bed is the Flinty-biotite schist, next the Little Limestone, which occurs repeatedly and has in no case been produced by Newer Granite alteration. The feature of this rock, too, is its fine grain. It clearly consisted originally of an admixture of fine quartz, some felspar, and a considerable amount of chlorite. The fine chlorite acts at a specially low temperature on the quartz, and the rock becomes indurated and, unless the material be afterwards crushed, retains this induration, accompanied by a finely crystalline condition. At times another rock shows this hornfels type of alteration; but in this case it is not so finely crystalline. This is the felspar-hornfels of the Glen Callater type, which occurs twice in the Falar area. A section shows that this is even a better example of hornfels alteration than the Glen Callater rock. It is at least fifteen miles from the Lochnagar granite and a great distance from any Newer Granite intrusion,

Digitized by Google

Mr. Barrow. while the Glen Callater rock is actually inside the Lochnagar granite. It is thus perfectly clear that the hornfels structure of this rock has nothing to do with the Newer Granite mass of Lochnagar, and that this gneous mass has produced practically no effect on the Highland rocks, the crystallisation of which is obviously pre-granitic.

Turning now to the area east of Balmoral there is no sign of increasing alteration in the Highland rocks as we approach the eastern margin of the Lochnagar complex. The lines of very slow increasing alteration trend east and west at right angles to that margin. With material of similar composition, it is found that these rocks possess a common feature and one that distinguishes them from all others in the Highlands. The true hornfels rocks, when in an area of high or moderately high alteration, are distinguished by the occurrence of a great number of minute flecks of biotite distributed through the rock. (This mineral usually posseses a rich brown colour.) The evidence already obtained makes it practically certain that this flecking is due to the (early) action of the chlorite on the quartz which produced an induration that made it difficult for material to migrate. This dissemination of flecks of biotite never occurs in a thoroughly schistose or gneissose rock.

Newer Igneous Masses.—A considerable mass of Newer Granite has been mapped on the north-west side of the Tilt Valley. Part of this area was formerly surveyed by Mr. Dakyns, and specimens were collected which have been described by Mr. Teall. Briefly, the complex consists of variations of diorite, the greater part of which is distinctly basic, and modifications of granite, the bulk of which is markedly acid and contains much free quartz. But there are some phenomena of extreme interest associated with these intrusions. They are connected with the foliation of certain small intrusions, the occurrence of dyke areas and dyke-free areas, and also with what may be conveniently called the "roof" of the complex. The phenomena associated with the latter are specially interesting in view of the idea they suggest as to the mode of intrusion of the granite. The composition of the material around and above the intrusion (Quartzite and Moine gneisses) is prohibitive of the view of the formation of the granite approximately *in situ*, by absorption of the surrounding material, while the mapping of the "roof" shows that the idea of upheaval of the overlying rocks is equally unlikely. The mode of occurrence of the acid material suggests a new, and possibly in many cases a far more reasonable, explanation of the mode of intrusion of these granite masses. It is seen that acid material is injected between the roof or enclosing wall of the older diorite and the diorite itself. The mode of occurrence of these injections suggests that the acid granite did not lift the roof up, but pushed the older more basic igneous material down in many cases. It seems as if the igneous material had forced its way up one or more ducts till a point was reached where it could no longer remain fluid or plastic enough to flow. It then spread out in the form of sheet, working downwards to a warmer and not upwards into a colder environment.

Digitized by Google

Mr. Barrow.

The portion of the great drainage area of the Tay that lies above Pitlochry varies greatly in character. One feature is common to all the minor valleys that together compose the area. They are locally covered with peat and drift, the latter being a softish clay or gravel. In consequence they all bring down a certain amount of highly micaceous fine mud and peat held in mechanical suspension.

To the N.E. of Pitlochry there are thick masses of limestone; these cause a considerable amount of lime in solution to enter the main drainage valley. A similar limestone area occurs on one side of the Tilt above Blair Athol; this again imparts much lime in solution to the water of the Tilt.

On the N.W. side of the Tilt, particularly in the Tarf Valley, are considerable masses of granite and granite drift. The latter contains a large proportion of decomposing felspar, which gives out a large quantity of soluble silica when rain percolates through this granite drift.* In flood times the water in the Tarf is almost black with peat.

The upper part of the Garry supplies a fair amount of silica, the rocks over which the rainfall passes being mainly felspathic gneisses. There is little lime in this area.

The Tummel drains a large area of granite and quartzose gneisses, much of the ground being covered with peat. It passes through two large lakes, Loch Rannoch and Loch Tummel, and, except in specially heavy floods, the Tummel water is greatly filtered and cleared of impurity in its passage through these lakes.

Mr. Craig.

Glen Feshie District.—In the area surveyed by Mr. Craig in the Glen Feshie district, the rock consists of Moine schists of the siliceous type, with many small intrusions, chiefly granitic.

Two types of the schists can be distinguished, but it is not possible to separate them on the field maps. The first consists of flaggy quartz-biotite-gneisses or schists, highly granulitic, and occasionally with fairly thick massive beds; these rocks contain very little muscovite, and that chiefly along planes where differential movement was greatest. The second type is much more highly felspathic and does not weather into flags, muscovite is more abundant, though biotite is still always present. On a cross fracture the beds often appear almost granitic in character.

Newer Igneous Rocks.—Intruded into these schists, small diorites and lamprophyre dykes and sills are seen; they are of the usual type of the newer diorites and lamprophyres of the Braemar district.

Granitic intrusions are frequent, as might be expected, in an area lying between the Cairngorm granite on the N.E., and the Beinn Dearg granite on the south. An extension of the

* A singularly perfect illustration of the quantity of soluble silica washed out of granite drift is afforded by the mass of diatomite on Duniet Moor, Aberdeen. The supply of silica for this material is derived exclusively from the great mounds of granite drift, the rain falling on the mounds percolating them and issuing charged with silica.

Digitized by Google

Mr. Craig. Beinn Dearg (Perthshire) mass crosses the county boundary, and about two square miles of granite have been mapped on the Inverness-shire side, where it forms Meall Tionnail. This Meall Tionnail granite resembles very closely the Cairngorm granite, especially that type seen on Beinn Bhrotain, *i.e.*, very acid, with very little biotite, and fairly coarse in grain. Indeed at one part of the margin the Meall Tionnail granite is practically a binary granite, very coarse, and with a few large scattered flakes of biotite. It is coarse right up to the margin. This mass is also characterised by the absence of the much more acid intrusions which are so common in many parts of the Cairngorm mass, and by the fact that it does not seem to be affected by fault movements. From these data it appears probable that the Meall Tionnail granite represents one of the latest phases of the Cairngorm granite intrusions.

Apart from the large mass of granite forming Meall Tionnail, there are no acid intrusions of any great extent; though veins are very numerous, they never attain large dimensions. These veins vary in character considerably, aplites, fine and coarse granites, and pegmatites are frequent all over the area except in the N.W. part, where one passes gradually from an area characterised by the intrusion of plutonic rock of the Newer Granite to an area in which the intrusions have been cooled more quickly, and appear as quartz-porphyries and felstones with chilled edges. One well-marked sill has been mapped, its eastern extremity being granite, and its extension to the N. and W. being quartz-porphyry. In the intermediate area specimens ranging between granite and quartz-porphyry can be obtained; a phenomenon observed near Braemar, where the Auchindryne granite passes westward into quartz-porphyry.

The granite veins frequently exhibit coarse central zones of pegmatitic material, and sometimes have coarse pegmatite margins also, thus resembling the later vein intrusions in the granite mass of the Cairngorms.

A small part of the margin of the Cairngorm granite, east of the river Eidart was examined. It presented no remarkable characteristics, but the metamorphic rocks within half a mile of the junction are pierced by a great number of granite veins, coarse red pegmatites and pale aplites, all of which are of the Newer Granite type. There are no foliated muscovite pegmatites of the Chest of Dee type in this locality.

Newtonmore District.—In the area surveyed from Newtonmore, the rocks encountered are the same types of Moine schists, with minute infolds of muscovite-biotite schist in the western part of the area. The development of pegmatite veins in this area presents some points of interest. These veins vary in breadth, from an inch or two up to six feet or more. They are usually along the bedding planes, but sometimes cross them at high angles. No single vein can be traced far. In composition they are usually coarse muscovite pegmatites never showing any signs of being more quickly cooled at the margins; the crystallisation is uniform throughout. These veins never show signs of having been affected

Digitized by Google

by dynamic metamorphism, and no contact metamorphism has taken place at their margins, but the country rock appears to have crystallised simultaneously with the pegmatite, the crystals interlocking in the most intimate manner. Mr. Craig.

When these pegmatites are intruded through rocks rich in biotite, the pegmatites contain a considerable quantity of biotite also, even to the exclusion of muscovite in thin veins, but the usual type in a quartzo-felspathic country rock, not containing much biotite, is a muscovite pegmatite without biotite.

From these facts it appears probable that segregation has taken some part in the formation of these veins, and that they are contemporaneous with the regional metamorphism of the district.

In the area surveyed in Glen Feshie, there is very little soil derived from the disintegration of rock *in situ*. The higher parts of the hills are covered with a stony rubble of the Moine schists, while the area occupied by the Meall Tionnail granite presents a surface of weathered granite blocks and sand.

The lower parts of the glen are entirely covered with sandy morainic *débris*. The greater part of the area is covered with peat which occasionally attains a depth of ten feet.

No part of the ground is cultivated, there are no quarries, and no population, as there are no inhabited houses in the area.

The water supply is abundant, but liable to be somewhat peaty during floods.

The area is part of the Glen Feshie deer forest, and the high ground and alluvial stretches along the river Feshie furnish the rough pasture most favourable to deer. A considerable number of grouse breed on the lower ground, but are not shot in this part of the forest.

To the area surveyed from Newtonmore the same remarks apply, but there are one or two houses with small patches of cultivated ground on the alluvial soil and fluvio-glacial gravels along the river Truim.

The land affords grazing for a few sheep, but its chief value is as a grouse moor, the low lying heather-covered areas affording excellent cover and feeding for the birds.

Aberfeldy District.—The mapping of the Green Bed outcrops south of the Tay, in Sheet 55, has been completed by Mr. Craig, and has, as usual, thrown considerable light upon the structure in this district. The presence of several important faults not previously recognised has been demonstrated, and additional evidence has been obtained regarding the flat-lying type of folding.

The progressive metamorphism northward, to which attention was called in last year's report, can now be considered in greater detail, microscopic examination of a series of specimens chiefly from the Green Beds having been made. A series of specimens taken, roughly speaking, from south to north, exhibits the increase in metamorphism strikingly. Pebbles are very conspicuous in the more southerly outcrops, while garnets are absent, the rocks consisting of biotite-hornblende schists with pebbles of quartz more or less numerous, and a certain amount of granulitic quartz and felspar in the matrix. The quartz pebbles, as pointed

Digitized by Google

Mr. Craig.

out by Dr. Flett, consist of lenticles more or less granulitized and showing all stages in the breaking down into a granular mosaic. The felspar Dr. Flett finds to be secondary, and from its low refractive index, as ascertained by Becke's method, must be either albite or orthoclase.

In specimens from outcrops farther to the north, and especially in beds of originally finer material, on which the dynamo-metamorphism has taken greater effect, a further stage in the thermometamorphism is seen. The hornblende still appears in feathery ill-defined prisms, but attacking the quartz pebbles and the granulitic quartz of the matrix. Garnets, small and idiomorphic, are common, while epidote and iron ores are also present.

A gap of from one and a half to two miles separates the outcrop of the Green Beds south of the Tay from that north of the Tay. Two specimens from the outcrop north of the Tay have been microscopically examined. These show such an advanced stage of metamorphism, that they can hardly be distinguished in a microscopic slide from the fine edges of epidiorite sills. No traces of clastic structures are present, and the rocks consist chiefly of hornblende with a few garnets, some quartz and felspar, sometimes biotite, and accessories such as rutile and apatite.

It is noticeable that the garnets usually act as "eyes" in the epidiorite sills, the hornblende of the matrix curving round them, and often leaving triangular patches of quartz or felspar at either end. In the Green Beds, the garnets do not seem to have acted in this manner as a rule, the hornblende crystals abutting against or enclosing them. The foliation of these green beds also seems to be rather more regular than that of the edges of epidiorite sills.

In hand specimens several methods of distinction are possible: the epidiorites have the rusty weathered crust characteristic of igneous rocks; the fracture also resembles that of an igneous rock, and the lustre on a fresh cross fracture is greater than in the case of the Green Beds. In those specimens of Green Beds which most closely resemble the epidiorite sills, the fracture is more earthy, and the weathering and jointing are those of a schist of sedimentary origin; the lustre upon a fresh cross fracture is not so great, and the colour of the hornblende on a cross fracture is lighter, being more distinctly green as compared with the almost black colour of the hornblende in the epidiorites. These characteristics are, as a rule, sufficient to distinguish the edges of epidiorite sills from much altered hornblendic Green Beds, where field evidence is not available.

Specimens from other horizons have been selected and examined microscopically for the purpose of elucidating the progressive metamorphism, but space does not permit of any description of them being given here.

District between Pitlochry and Blair Atholl.—Mr. Craig thus summarises the results of his revision and re-survey of about fifteeen square miles of the ground between Pitlochry and Blair Atholl in October, November, and part of December. It was

Digitized by Google

anticipated that important evidence regarding the succession of strata would be obtained in this district, and special attention was accordingly given to evidence bearing in any way upon that question. Mr. Craig.

The area revised comprises the rocks from a horizon not far to the north of the Loch Tay limestone outcrop, a sill of epidiorite marking the boundary, and so north-westward, northward, and north-eastward to the first main outcrop of Blair Atholl limestone. Geographically, the various members of the series are arranged as follows, the section in the Tummel and Garry Rivers being taken as typical :—

(5) Blair Atholl Limestone.
(4) Black Schist.
(3) Quartzite.
(2) So-called Graphite Schist.
(1) So-called Calc Sericite Schist.

(1) The zone to which the name of calc-sericite schist has frequently been given, consists of felted mica schists and phyllites, often with quartz veinlets, but becoming more calcareous near the top, where thin limestones are observed, and calcareous sericitic beds, which have frequently developed bladed crystals of actinolite. These schists and limestone beds will be described in the explanation of Sheet 55 as the Beinn Lawers schists. A very easily recognised thin brownish limestone or dolomite forms the top of this group.

(2) This group consists of a dark leaden-coloured schist, to which the name Graphite Schist has frequently been given, because some of the upper beds are occasionally markedly graphitic. A thin black impure limestone has been mapped near the top of this group.

(3) The Quartzite has been spoken of as the Banffshire, Schiehallien or Central Highland Quartzite. The margin is fine, but a pebbly band is frequently seen a few feet within the mass.

(4) North of the quartzite comes an outcrop of dark leaden-coloured schist which is associated with a mass of (5) Blair Atholl limestone. Repetitions of the quartzite, dark leaden-coloured schist and limestone occupy the surface in the area to the northward. Details, most of which have come to light in the re-survey, are omitted in the above. Associated with limestone, a greater or less thickness of variable schists are sometimes observed, and Phyllitic schists, homotaxial with the black schist, appear in the northern part of the area.

That the series is an upward succession from the Loch Tay limestone to the most southerly outcrop of quartzite has been recognised for many years.

The evidence regarding the succession obtained during the re-survey can be considered conveniently under three heads: (*a*) Structural evidence, which can be considered irrespective of folding, dip, or pitch; (*b*) Petrological evidence; (*c*) Evidence from observation of pitch, and discordant junction of different members of the series.

Digitized by Google

Mr. Craig.

(*a*) The first point of importance is the identification of the dark schist south of the main quartzite outcrop, with that north of the outcrop, *i.e.* (2) is the same as (4). On Meall Uaine, the so-called Graphite schist can be traced round the folds of the base of the quartzite into the black schist to the northward, associated with the Blair Atholl Limestone. There is no drift obscuring the ground, and the section is remarkably clear. The basal edge of the quartzite is seen folded with the under-lying schist, and usually much drawn out by shearing at the actual margin; but a few inches farther in, the quartzite is fairly solid.

Minor zones in the black schist can also be identified on both sides of the outcrop of quartzite. The thin dark limestone already alluded to is seen in several localities south of the quartzite outcrop, and near the summit of Meall Uaine it is found more highly altered, and beginning to develop Tremolite crystals. North of the quartzite it has the same appearance, but as we proceed north-eastward into a region of greater metamorphism, the Tremolite becomes more conspicuous and more highly crystalline, till the rock presents the appearance of the well-known Tremolite limestone, which has been so often recorded as a zone in the black schist, associated with the Blair Atholl limestone.

This identification of the black schist with the so-called Graphite schist, is further confirmed by the mapping of the Ben Lawers Schist, with its characteristic thin limestone band, round from south to north of the outcrop of the quartzite.

This evidence is sufficient to establish the fact that the quartzite is the highest member of the series, lies above the black schist, and when it comes in contact with the Blair Atholl limestone, as near the head of Allt a' Mhagain, must be above that deposit also.

All the rest of the evidence, while amply confirming this conclusion, bears more directly upon the relation of the quartzite to the other rocks in the district. The first point of importance is that no exposure of the Blair Atholl limestone has been observed south of the main outcrop of the quartzite. Again, the margin of the quartzite, and it follows from the evidence stated above that only one margin of the quartzite is seen in this district, comes in contact with the Blair Atholl limestone, variegated schists sometimes associated with the Blair Atholl limestone, the black schist, the Tremolite limestone in the black schist, and the Ben Lawers schist, with its thin band of limestone. It may also be mentioned here that the Quartzite comes in contact with a large laccolitic sill of foliated hornblende rock intruded between the Ben Lawers schist and the black schist, and also with a thin sill of garnetiferous hornblende schist intruded in the black schist. In the third place, the margin of the quartzite is seen to transgress the outcrops of other members of the series, as is indeed necessary in order for it to come in contact with all the above-mentioned groups. This transgression can be seen clearly in ground free from drift.

Digitized by Google

From these facts it is possible to deduce two alternative explanations: (1) that most of the upper groups die out sporadically to enable the quartzite to apparently descend in the series, or (2) that there is presumptive evidence of an unconformable overlap of the quartzite upon the lower members of the series. Mr. Craig.

(*b*) Petrological evidence can be considered next, to see whether it confirms either of the above hypotheses.

A very striking fact came to light during the examination of the basal beds of the quartzite in different localities, *i.e.*, that these basal beds vary in character and composition according to the nature of the underlying rock. Coarse pebbly beds are not infrequent near the base of the quartzite, but the actual margins are almost invariably fine in grain, and appear to contain material derived from the adjacent rock. That this intermingling of material has not been caused by the disruption of bedding planes under shearing forces and the subsequent rearrangement of the affected material, is proved by the perfect continuity of the bedding planes, and the fact that the intermingling of material extends farther into the quartzite than any marginal belt of special shearing due to the sudden change in coefficient of elasticity in passing from a shale to a quartzite. The only possible explanation of the phenomenon is that contemporaneous erosion accompanied the deposition of the basal layers of the quartzite. The thickness of these bands in which evidence of this contemporaneous erosion can be obtained seldom exceeds two feet; they sometimes contain pebbles of quartz and felspar very little affected by shearing. The gradual passage of these bands into the purer quartzite is regular and well marked. Where the quartzite comes in contact with the black schist the basal laminæ of the former rock consist of rusty impure sandy micaceous schist containing muscovite, biotite, graphite (?) in some places, iron ores, and occasionally needles of tourmaline. These beds are usually soft and rusty, and are separated by films of sandy micaceous schist of a type differing completely from the normal black schist. This marginal type of the quartzite has been described in other areas as the Coire Neid type. When the quartzite comes in contact with the Tremolite limestone band in the black schist, the basal beds consist of impure calcareous quartzite, which is usually very rotten and friable, owing to the lime dissolving out under weathering processes and leaving the silica. There is not a sufficient area of contact between the quartzite and the Blair Atholl limestone in this district to make it possible to describe the general type of the marginal beds of the quartzite under these circumstances, but where the quartzite comes in contact with the variegated schists associated with the Blair Atholl limestone, and with the garnetiferous hornblende schist still in the black schist, the basal beds are represented by a very variable series of schists composed of quartz, felspar, muscovite, biotite, garnets, and occasionally hornblende or calcite, each constituent varying in quantity in different bands or different localities, but the whole, by becoming more quartzose, gradually passing into pure quartzite.

Digitized by Google

Mr. Craig.

Throughout a great part of the area where there are no large outcrops of quartzite small infolds of the base of the quartzite are frequent. These infolds are sometimes very minute, but are invariably recognisable, and present the same phenomena of contemporaneous erosion and deposit.

Thus it has been seen that the base of the quartzite not only transgresses the boundaries between other members of the series but that its deposition was accompanied by local erosion in this area, and it follows that the quartzite is not conformable to the other members of the series. How great the unconformability may be it is impossible to say from the evidence in this district, but the absence of the Blair Atholl limestone from the area south of the first main outcrop of the quartzite is very significant; the limestone may either have never been deposited or it may have been entirely removed by denudation.

(*c*) Observations of the pitch of the folding confirm what is stated above with regard to the order of succession; Ben Lawers schist, black schist, Tremolite limestone, variegated schists, and Blair Atholl limestone are all seen to pitch below the quartzite.

The actual discordance between the bedding of quartzite and black schist can be seen in several places both south and north of the main quartzite outcrop, where the bases of folds of that rock are seen in contact with the black schist. Hand specimens can even be obtained showing this discordance, which may appear only as current bedding, but may mark a very considerable unconformity.

The succession, then, in this district, is proved to be as follows, in descending order:—

4. Quartzite.
3. Blair Atholl Limestone.
2. Black Schist, with Tremolite limestone near the top.
1. Ben Lawers Schists, with thin limestone at the top.

A gentle unconformability, which may be only local or may be of considerable magnitude, occurs at the base of 4, and occasionally cutting out 2 and 3 completely.

A point of great interest in the district is the development of pre-folding basic intrusions. Mr. Barrow pointed out several years ago that the source of at least one of the hornblende schist sills can be seen on Beinn Vrackie. It takes the form of a large flattened laccolite, spreading out into a thick sill, which thins out rapidly to the south and west, while to the north and east it extends farther. It is possible that there is more than one intrusion, but as the ground has not been entirely surveyed, it is impossible to be certain on this point. The main laccolite, which causes the strike of the strata to be deflected round it in a most regular manner, is intruded between the Ben Lawers schist and the black schist, approximately, but it also gives off a minor sill, which occupies a low horizon in the black schist. The igneous mass has been thrown into large rolling folds, while the surrounding rocks, of sedimentary origin, were compressed into

Digitized by Google

a vertical isocline. The edges of the main sill, however, and the minor sill, have shared in the intense folding of the sedimentary series. Mr. Craig.

No detailed examination of the petrological characters of these intrusions has yet been made. It will be sufficient to state that the main intrusion, where it is least affected by movement, is a holocrystalline hornblende rock, very basic in composition, while the margins are represented by finely laminated hornblende schists, nearly always containing some garnets.

The sill in the black schist is invariably a very garnetiferous hornblende schist, the garnets sometimes attaining a diameter of an inch or more, while biotite is frequently present.

The main laccolite has caused considerable alteration of the hornfels type in the black schist, the latter rock being intensely indurated, so much so that, for a distance of from five to twenty yards from the junction, the hornfels has been able to resist, to a great extent, the shearing forces consequent upon the folding, so that it exists now as a compact hornfels.

It is in the relations of the quartzite to these basic intrusions that one of the most interesting problems of this district is found.

At Aldclune, throughout the Pass of Killiecrankie as far as a point just above the junction of the Garry and Tummel, and for several square miles to the east and north-east, the base of the Quartzite is continually coming in contact with the garnetiferous hornblende schist sill in the black schist. This sill is folded again and again with the base of the quartzite, but in no instance has it been seen to intrude in the quartzite. Following the lower edge of the latter, the sill is sometimes seen to be separated by a few feet of black schist from the arenaceous rock, sometimes a thickness of from a few inches up to six or eight feet of the sill is seen in actual contact with the base of the arenaceous group, while sometimes the sill appears to be absent altogether. Where the base of the quartzite descends in the series to the horizon of the Ben Lawers schist, no trace of this sill is seen.

Where this minor sill is in actual contact with the quartzite, a remarkable variation in the composition of the latter rock is noticed. The lowest layers for a thickness of from a few inches up to about three feet are not quartzite, but consist of highly quartzose rocks of variable composition containing biotite, some white mica, garnets, and very frequently hornblende. In these rocks the bedding is well marked, and on fresh fracture they present the appearance of banded, bluish, rusty-weathering quartzose schists, with the fracture and typical weathering of quartzite. In the Pass of Killiecrankie excellent waterworn sections of these marginal rocks are seen, biotite being the most abundant ferromagnesian mineral. Where hornblende occurs it is usually in bladed or feathery crystals lying at all angles to the bedding; garnet is always present in such cases, while biotite is less abundant, and white mica is more conspicuous.

The various bands differ in composition by the increase or decrease of one or more of the constituent minerals, but all varieties, by becoming gradually more quartzose to the exclusion

Digitized by Google

Mr. Craig

of impurities, pass into the solid quartzite. Sometimes an almost pure quartzite with a few garnets is observed. The pebbles, which not infrequently characterise the lower beds of the quartzite, have occasionally been detected in these marginal beds, and in such cases they are very little affected by shearing stresses, showing that there has been very little differential movement during the folding.

Large rounded masses or short veinlets of quartz are sometimes observed at the junction with the sill, and even within the margin of the originally igneous rock.

These marginal beds may be repeated by folding, so that they cover a considerable area, but where a good section is examined they can always be proved to be only a few feet, or perhaps only a few inches, thick.

Where the Quartzite lies at a higher horizon than the sill, and the sill is enclosed by black schist on both sides, none of the above phenomena are noticed, either at the margin of the quartzite or at the margins of the sill.

From this evidence it seems probable that this sill has been intruded prior to the deposition of the quartzite, that the latter rests unconformably upon it in many localities, and that the basal layers of the arenaceous rock contain material derived from the denudation of the originally igneous rock.

Turning to the evidence from the large parent sill or laccolite, some confirmation of this view is found, but till the ground has been fully surveyed, it is impossible to speak conclusively.

It has been seen that the black schist has been hornfelsed by the intrusion, and that this alteration can still be detected. Now in several localities the base of the quartzite traverses the outcrop of the black schist and comes in contact with the hornblendic intrusion. In such cases no induration of the quartzite has been observed, but, on the contrary, the marginal beds present a rusty decomposed aspect, containing many impurities. In one and the same locality this rusty edge of the quartzite may be seen in contact with both the hornfelsed black schist and the coarse hornblendic sill.

In one or two localities also the base of the quartzite appears to traverse the outcrop of this sill or laccolite, and comes in contact with the underlying Ben Lawers schists.

The area examined is singularly free from faults of any magnitude and from igneous intrusions older than the folding.

The folding is never very deep, but is perfectly isoclinal. The area comprises part of the centre of the great fan structure of the southern Highlands; in consequence there has been none of the later shearing movements, and the grade of dynamic metamorphism is low, the shearing consequent on the folding being the only movement of the kind to which the rocks were subjected, with the exception of some strain slip cleavage developed in the finer and softer schists.

Where the thinnest edges of folds of the quartzite are enclosed in the black schist considerable evidence of shearing movement

Digitized by Google

is observed, but within a few feet the quartzite becomes fairly massive, and pebbles are often very little drawn out. Mr. Craig.

In the area to the south of this district where the folding is flat or gently inclined, no traces of pebbles can be seen for a distance of from six to ten miles from this central axis.

The thermometamorphism is considerable, though nowhere intense; aluminous silicates have not been developed in the argillaceous rock, nor calc-silicates to any extent in the limestones, but all the rocks have been recrystallised.

Strath Tummel District.—The results of the re-examination of about 15 square miles of ground in the lower portion of Strath Tummel are thus given by Mr. Wilson. Mr. Wilson.

From south to north the various zones are found in the following geographical order—

(4) Limestone and black schist.
(3) Quartzite.
(2) Black schist with little black limestone.
(1) Ben Lawers schist.

(2) *Black schist with little black limestone.*—The greater portion of this group is a dark-blue schist. At some localities these dark bands alternate with grey schists with garnets, and occasionally the series becomes coal-black towards the top and contains graphite. The little black limestone is situated in this group.

(3) *Quartzite.*—This division varies from a solid white quartzite to pebbly quartzite and quartz-schist.

(4) *Limestone and black schist.*—The limestone is a blue to steel-grey holocrystalline rock, and the black schist is identical in every respect with the dark blue and black schists of group 2.

(1) *Ben Lawers schist.*—On the east side of the Frenich Burn there is a small area of these schists, which are entirely composed of large bladed crystals of actinolite in a sericitic base. The actinolite schist, along with the spotted brown limestone, forms a characteristic band at the top of the Ben Lawers schist. On the craggy ridges to the west of Pitlochry the upper and calcareous portion of this group contains two well-marked infolds of the black schist.

(2) *Black schist.*—To the west of the River Tummel at Pitlochry no alteration has been made on the previously traced outcrop of this group, but the occurrence within it of the little black limestone was proved at two different localities. From this southern outcrop, at a point one mile west of Farragon, the black schist has been traced continuously across the watershed into Strath Tummel, where it stretches from near the head of the loch to a distance of two miles below its outlet. All through Strath Tummel the different members of this zone are constantly repeated by the shallow isoclinal folds. As the result of this folding the boundary lines are much involved. The small black limestone and black tremolite rock has been observed at several localities within the area to the south of Loch Tummel.

On the north side of the river and loch this same zone of black schists has been continuously traced from the foot of Glen

Digitized by Google

Mr. Wilson. Fincastle to a point north of Portnellan House, where it is truncated by the Loch Tay fault. This area of black schist is only separated from the outcrop of the Blair Atholl limestone and its black schist on the watershed between the Rivers Tummel and Garry, near Lochan na' Leathain, by a narrow belt of ground obscured by superficial deposits 300 yards wide, and there is a strong presumption that the black schist is continuous across.

To the north-east of the large Strath Tummel belt, and separated from it by quartzite, another area with a very irregular boundary stretches from near Fincastle House to the River Garry, and is continuous with the black schist mapped by Mr. Cunningham-Craig on the east side of this river, and several small inliers occur within the quartzite at the foot of the Tummel Valley.

(4) *Limestone.*—Within the area of the black schist already described as extending west to the Loch Tay fault, and about a quarter of a mile east of Loch Tummel Inn, the cliff called Creag Mhor is formed of a mass of steel-grey limestone, identical in character with the Blair Atholl limestone as developed a little to the north-east at the head of Glen Fincastle, and there can be little doubt that it is a western extension of that seam. In this exposure the limestone is visible in three separate folds surrounded by and folded with the black schist. In the immediate vicinity of Creag Mhor there are two other separate outcrops of a similar limestone associated with the same belt of black schist.

At the head of Glen Fincastle near Edintian and the black schists, there is a considerable outcrop of black limestone, which has been recognised by Mr. Wilson as the "little black limestone." He regards it as the same limestone which occurs in the southern outcrop, and from this correlation as a necessary consequence, the identity of the black schist in the two areas follows. The triangular area on the south side of the River Garry is occupied by Blair Atholl limestone and black schist, and there can be no doubt we are dealing with the same black schist and limestone as at Creag Mhor, because at the head of Glen Fincastle, the little black limestone and black schist both dip under the Blair Atholl limestone.

Quartzite.—The character of this rock varies considerably over this area. To the S.E. of the junction of the Tummel and Garry on both sides of Loch Tummel, and at several other localities, the black schist is immediately overlaid by a solid white quartzite containing felspar. In the direction of Farragon, this massive type gives place to a grey quartzite with strong pebbly bands, either at the edge or else some little distance from it. The grey colour is due to small lenticular fragments of black schist which are enclosed in the quartzite matrix. This fact seems to indicate that local denudation of the black schist was taking place at some point or points in this district, during the period of deposition of the quartzite.

At several points in Strath Tummel, the edge of the quartzite next to the black schist is slightly calcareous, and generally occurs as a weathered crumbling gritty rock. The

Digitized by Google

pebbly edge of the quartzite is found as far as Loch Tummel, and on both sides of the belt of black schist which extends northwards from Farragon. From Glen Fincastle to the Pass of Killiecrankie, the quartzite is very much folded and inter-felted with bands of black schist. Here the edge rock of the quartzite is essentially a quartzose schist with a rusty brown weathering, and frequently contains biotite, tourmaline, and other minerals. Mr. Wilson.

Basic intrusions.—Throughout the pass of Killiecrankie, a much folded epidiorite sill with garnets (sometimes 1 inch in diameter) is associated with the black schist. This sill occurs at many points to the west, and as far up Strath Tummel as the foot of the loch. It is sometimes intrusive in the black schist, but is more frequently in close contact with the quartzite on the one side, and the black schist on the other.

Relation of the Quartzite to the other Zones.—The occurrence of black schist fragments in the pebbly quartzite has already been mentioned as evidence in favour of the view that local erosion of the black schists took place in the present region during the deposition of the quartzite. At Creag Mhor the quartzite is seen to transgress from the Blair Atholl limestone on to the black schists. To the north of this point, the same edge of the quartzite is successively in contact with the Blair Atholl limestone and with the black schist for a short distance. Over the portion of the area (already described) occupied by the pebbly edge of the quartzite, the latter occurs next to the black schist, but at the Frenich Burn, this pebbly edge for some distance is in contact with the "Ben Lawers schist," exposed in the small area already noticed.

Within the triangular space on the south side of the River Garry occupied by black schist and Blair Atholl limestone there is a considerable area of solid white quartzite, the outer edge of which rests on black schist and the inner edge on limestone. This same belt of limestone passes outside the quartzite and is then on both sides in contact with black schist.

These facts afford strong presumptive evidence in favour of an unconformability between the quartzite and the other members of the Highland schists in this area.

II. PALÆONTOLOGICAL WORK.

Mr. Peach, the Acting Palæontologist, has prepared the following summary of palæontological work in Scotland during the past year. Mr. Peach.

The Palæontological department in Scotland was carried on during the season by Mr. Peach, assisted by Dr. C. B. Crampton, Mr. A. Macconochie, and Mr. D. Tait. Assistance had also been afforded by the following specialists outside of the Geological Survey, viz., Dr. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston.

The number of fossils gathered by the Fossil Collectors during the year is 1191, of which 31 are from the Ludlow and 74 from the Downtonian rocks of Lanarkshire, 20 from the Lower Old

Digitized by Google

Mr. Peach. Red Sandstone of Fife and Dumbarton, 298 from the Carboniferous rocks of Berwickshire, Fife and Arran, 719 from the Secondary rocks of the Isle of Skye, and 50 from the Post-Tertiary Clays of Loch Lomond. During the season the fossil collectors were much engaged in collecting rock specimens, which they gathered to the number of 2,693. In view of the publication of the memoir on East Fife Sir Archibald Geikie desired that collections of fossils should be made from certain shaly beds of the Lower Old Red Sandstone that emerge from beneath the great volcanic platform of the Ochils and are exposed on the shore of Wormit Bay on the south of the Firth of Tay nearly opposite Dundee, and also from Parkhill in the same neighbourhood whence Professor Fleming obtained the first described specimens of *Parka decipiens*. Collections were accordingly made by Mr. Macconochie. The fishes, determined by Dr. Traquair, are *Mesacanthus Mitchelli*, *Ischnacanthus gracilis*, and *Climatius scutiger*; the other forms, determined by Mr. Peach, are *Pterygotus anglicus*, *Eurypterus sp.*, and *Parka decipiens*. The assemblage of fossils is like that found at Duntrune and Balruddery on the opposite side of the Firth.

For the same purpose it was found to be highly desirable that certain plant bearing beds in the Lower Carboniferous rocks exposed on the shores of East Fife should be specially searched for plants. Mr. Kidston, accompanied by Mr. D. Tait, devoted a few days to this investigation, with the result that they obtained a considerable amount of material. The results of Mr. Kidston's study of the plants obtained will be incorporated in the forthcoming memoir. One of the plants, *Sphenopteris foliolata*, Stur, obtained by them is new to Britain.

At the instance of Mr. Gunn, and for the purpose of obtaining additional information for the forthcoming memoir on the Geology of part of Arran, Mr. Tait made a collection of fossils from the shingle beach on the north side of Catacol Bay, in Arran, as Mr. Gunn thinks that there is strong presumptive evidence that Carboniferous Limestone rocks occur in the sea just outside of Catacol. Mr. Peach determined the fossils, which appear to denote the horizon of the Upper Limestone group of the Carboniferous Limestone series of Scotland.

In order to follow up the discoveries made in the Ludlow and Downtonian rocks of Lanarkshire, Mr. Tait in the early part of the season made a considerable collection from these rocks in the Lesmahagow inlier in Lanarkshire. The fishes have been determined by Dr. Traquair, but no new points of morphological interest have been exhibited by the specimens. Several good specimens of *Pterygotus* and *Slimonia* were obtained by Mr. Tait from the site of the Logan Water Reservoir at present in course of construction.

In the autumn Mr. Kidston once more placed his valued services at the disposal of the Geological Survey, and, accompanied by Mr. Macconochie, made a search for rare fossil plants among the lowest Carboniferous rocks of the Border. The results are embodied in the accompanying report by Mr. Kidston.

Digitized by Google

While searching for plants they also obtained a valuable collection of fossil crustacea. They also made a very interesting discovery of pseudomorphs after crystals of salt in some shales of the Cementstone group of the Lower Carboniferous "Tuedian Beds" exposed in a scaur of the Blackadder Water near Allanton, in Berwickshire. The particular interest attaching to the find is the additional evidence this affords in favour of the view of the Cementstone phase of the Lower Carboniferous rocks being deposited in concentrated saline waters. Mr. Peach.

The following is Mr. Kidston's Report on fossil plants gathered from the Calciferous Sandstones of the Berwickshire border:—

"From the great interest of the specimens collected last year in Berwickshire (see Report for 1900, p. 174), a second visit was made towards the end of last season with the object of further investigating the fossil flora of the Calciferous Sandstone Series. The results were very satisfactory, and again led to the discovery of some new and interesting species. Mr. Kidston.

"Specimens were collected from the following localities:—

"From the Whiteadder Water, right bank, scaur under Edrom Church. (This locality is described in first notes, p. 174, as 'Right bank of Whiteadder, one-fourth mile west of Edrom House,' but the above designation is more definite.)

"To those recorded from this locality last year the following must be added:—

Sphenopteris elegans, Brongt.
This is the *Sphenopteris* sp. of first list.
Lepidodendron Veltheimianum, Sternb.
This is probably the *Lepidodendron* sp. of first list.
Stigmaria ficoides, Sternb. sp.
Cardiocarpus bicaudatus, Kidston.

"From right bank of Whiteadder Water at Willie's Hole, one mile east of Allanton. (In previous notes designated as from 'Right bank of Whiteadder, three-quarters-of-a-mile below Allanton'):—

Marchantites sp. Distinct from that already noted.
Lepidodendron Veltheimianum, Sternb.
Stigmaria ficoides, Sternb. sp., *var. undulata*, Göpp.

"From Road Cutting, north end of Norham Bridge over Tweed, a Nœggerathia-like pinnule was found in the upper portion of a cement stone band about twelve inches thick, in the shales a few feet above the level of the road.

"Some material showing plant structures was also collected, but this has not yet been examined.

"From small stream, about a quarter-of-a-mile N.E. of Ladykirk:—

Asterocalamites scrobiculatus, Sch. sp.

Digitized by Google

Mr. Kidston. "From Blackadder Water, right bank, about a quarter mile above Allanton Bridge:—

Lepidodendron spetsbergense, Nath.

"From Whiteadder Water, Bellsburn Scaur, near Chirnside:—

Aneimites sp.

"From Langton Burn, about four hundred yards N.N.E. of Gavinton, near Duns:—

Lepidodendron spetsbergense, Nath.

"Marshall Meadows Bay, two-and-a-half miles north of Berwick.

"These beds are above the Scremerston Coals, and below the position of the Hurlet Limestone:—

Sphenopteris (Diploehmema) Schutzei, Stur.
Cardiopteris polymorpha var. rotundifolia, Göpp. sp.
Asterocalamites scrobiculatus, Schl. sp.
Pinnularia.
Lepidodendron Veltheimianum, Sternb.
Lepidostrobus.
Stigmaria ficoides, Sternb sp.

"The specimens of *Asterocalamites scrobiculatus* were very fine, some being about a yard long. The *Stigmaria* showed the attached rootlets very beautifully, the rhizomes not being crowded, the rootlets were seen to extend from them at right angles, and about a foot long where they were broken over. Several rootlets were found which ended in a bifurcation.

"In addition to the two localities mentioned in the Report for 1900, viz., Langton Burn Road Cutting, north end of Norham Bridge, from both of which additional material was collected, some small blocks of a shelly limestone were found in the shingle on the Whiteadder Water immediately below the right bank scaur under Edrom Church.

"The plant remains in these are not so well preserved as those in the Langton Burn material, but the blocks contain much the same species. The Edrom material has, however, yielded a *Heterangium*, a genus not previously met with in Berwickshire.

"Microscopic preparations are at present being made from these materials showing plant structure, and already about one hundred and fifty slides have been prepared; but still a considerable amount of material awaits examination, so a Report on these specimens will be deferred for a future occasion. It may be mentioned, however, that the plants are of very great interest, and have added much to our knowledge of palæozoic botany."

Digitized by Google

A large collection of fossils was made by Mr. Tait from the Secondary rocks of the Isle of Skye during the season, to assist the Surveyors in fixing the horizons of these rocks as developed in Sheet 71 (one inch). They include fossils from each of the sub-divisions from the Infra-Lias or local representative of the Rhaetics up to the Oxford Clay. These fossils have all been sent to Mr. E. T. Newton for determination and classification. A few specimens of fossil wood showing structure collected from beds which may be of Triassic age have been submitted to A. C. Seward for examination. During the season a most interesting and important discovery was made by Mr. Clough who, as already stated in a former part of this report (p. 146), found cherty rocks in beds underlying the great Tertiary volcanic plateau in Skye, on the north side of Soay Sound in Sheet 70 (one inch). According to Mr. E. T. Newton, to whom the specimens were submitted, the cherts contain fossils which appear to belong to the Greensand division of the Cretaceous, an opinion also shared by Dr. G. J. Hinde (see p. 92). Mr. Peach.

Mr. Cunningham Craig, who surveyed the islands in Loch Lomond, wished a further collection of shells to be made from the Glacial Clays of Inchlonaig, which he considers to be of the age of the Hundred-feet Beach. Mr. Macconochie was, therefore, detailed to make the collection, which has been submitted to Mr. E. T. Newton, and a list of about 20 species has been supplied to Mr. Cunningham Craig for insertion in the forthcoming memoir of Sheet 38 (one inch).

Mr. Macconochie obtained from the Calciferous Sandstones on the banks of the Whiteadder, near Dunse, specimens of a fish spine in addition to one he had collected from the same locality many years before. The spines are considered by Dr. Traquair of sufficient interest to warrant the construction of a new species of *Gyracanthus*, the description of which by him is here given:—

"*Gyracanthus falciformis* n. sp. Traquair.—Length, four and a half to six inches; very decidedly and evenly curved antero-posteriorly from base to apex; stout at the base and rapidly tapering to the point. Inserted portion short, exposed part covered with closely set oblique ridges which get more and more oblique, till towards the point they are nearly parallel with the posterior margin of the spine; ridges tuberculated near the base, but tending to become quite smooth towards the apex. Posterior area narrow; unsymmetrical as usual; each of its margins being set with a row of very small oblique denticles. Dr. Traquair.

"The well marked configuration of these comparatively small spines (of which there are three pretty entire specimens in the Survey collection) prevents me from considering them to be the immature form of any known species."

Lists of fossils were drawn up by Mr. C. B. Crampton and Mr. D. Tait, under the supervision of Mr. B. N. Peach, for the Appendix of the East of Fife Memoir. Mr. Peach.

Digitized by Google

Mr. Peach. The following is a list of Specimens in the Survey collection figured in the Palæontographical Society's volume for 1901:—

A Monograph of the British Carboniferous Lamellibranchiata by WHEELTON HIND. Vol. ii, part 1.

Pteronites angustatus from Lower Carb. Series, Lawston Linns, Liddle Water. Plate v., fig. 1.

Pteronites angustatus from Calc. Sa. Series of Glencartholm, Dumfriesshire. Plate v., fig. 4.

Actinopteria fluctuosa from Clecklimon, Kilbride. Plate v., fig 8.

" " from the first limestone on the shore E. of Kinghorn. Plate v., fig. 2.

Actinopteria fluctuosa from W. Quarry at Salton. Plate v., fig 12.

Posidonomya corrugata from near Paisley. Plate vi., fig. 3.

" *radiata* from Calcif. Sa. Glencartholm, Dumfriessbire. Plate vii., fig. 7.

A Monograph of British Graptolites by G. L. ELLES and E. M. R. WOOD, edited by C. Lapworth. Part 1. Dichograptidæ.

Didymograptus serratulus from Minnoch Water, Glencaird Lodge, S. Scotland. Glenkiln Shales. Plate ii., fig. 7.

The Ganoid Fishes of the British Carboniferous Formations by R. H. TRAQUAIR. Part 1. Palæoniscidœ.

Elonichthys pulcherrimus (scales only). Plate xii., fig. 2.

" *serratus* (scales only). Plate xii., fig. 6.

III. MUSEUM WORK.

Mr. Goodchild. The Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Art, reports that during the year now at a close, the principal work done in the Geological Survey Gallery has been the re-arrangement of a large part of the collection of rock specimens, and the intercalation amongst these of new specimens of interest collected by the Survey officers, or given by others. A large number of the specimens of fossils have been retableted, and the descriptions written anew. In the course of this work the figured specimens have received special attention. A number of specimens of fossils from the Clyde Beds have been mounted and placed on exhibition. In addition to this, the important work of arranging the part of the collection which is not exhibited has been carried on. These specimens are arranged primarily under their respective biological headings, and secondarily under the number of the Ordnance Survey one-inch Sheets, so as to be available for immediate reference for lists. The collection of rock specimens placed in the glazed cases beneath the maps, has been catalogued with the special object of facilitating reference to such of the specimens as may be duplicates.

During the year the third edition of the Guide to the Geological Survey Collections was sold out, and a new edition was forthwith prepared and placed in the hands of the Director of the Museum for publication as before.

Digitized by Google

IV. MAPS, ETC., PUBLISHED.

Two sheets of the one-inch map have been published during the year, viz:—

No. 21, the northern part of Arran, part of Bute and the Cumbraes.
No. 38, embracing the districts of Loch Lomond, Loch Katrine and Callander.

Extra Official Publications, 1901.

BARROW, G.—"On the occurrence of Silurian (?) Rocks in Forfarshire and Kincardineshire, along the Eastern Border of the Highlands." *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328.

GUNN, W.—"On the Old Volcanic Rocks of the Island of Arran." *Trans. Geol. Soc. Glasgow*, vol. xi., p. 174.

————"On Recent Discoveries in Arran Geology" (read at British Association meeting, Glasgow). *Geol. Mag.*, Sec. IV., vol. viii., p. 565.

HARKER, A.—"Ice Erosion in the Cuillin Hills, Skye." With map. *Trans. Roy. Soc. Edin.*, Vol. xl., part II., pp. 221–252.

————"The Sequence of the Tertiary Igneous Rocks of Skye." *Geol. Mag.*, (4), vol. viii., pp. 506–509.

HILL, J. B.—"On the Crush-Conglomerates of Argyllshire." *Quart Journ. Geol. Soc.*, vol. lvii., pp. 313–327.

KYNASTON, H.—"On some tuffs associated with the andesites of Lorne.' *Trans. Edin. Geol. Soc.*, Vol. viii., pp .87–90.

PEACH, B. N.; W. GUNN, and E. T. NEWTON.—"On a remarkable Volcanic Vent of Tertiary Age in the Island of Arran, enclosing Mesozoic Fossiliferous Rocks." *Quart. Journ. Geol. Soc.*, vol. lvii., p. 226.

III.—IRELAND.

I.—FIELD WORK.

DUBLIN DISTRICT.

Mr. G. W. Lamplugh, District Geologist.
Mr. J. R. Kilroe,
Mr. A. McHenry,
Mr. H. J. Seymour,
Mr. W. B. Wright,
} Geologists.

Mr. Lamplugh and Staff.

The mapping of the drifts on the six-inch scale in the neighbourhood of Dublin was commenced in May, and the area represented on the one-inch Sheet 112, with so much of the margin of the adjacent sheets as lay within the slips of the six-inch maps required to complete that sheet, was completed by the end of November, the total area surveyed being 156 square miles. Attention was devoted exclusively to the drifts and other superficial deposits, though in traversing the ground a few facts were

Digitized by Google

Mr. Lamplugh and Staff.

noted in regard to the solid rocks which will be useful in preparing the new edition of the Memoir on Sheet 112, this memoir being at present out of print.

The MSS. six-inch maps of the former "solid" survey were examined, and a few notes relating to the drifts were transferred from them to the new working six-inch field-maps, but it was found that these notes were too scanty and the sketch-boundaries originally drawn for the drifts too diagrammatic to yield any material aid in the preparation of the drift-map. It has therefore been found necessary to make a thorough re-examination of the ground so far as the superficial deposits were concerned, but this has occupied much less time than would have been required if the re-examination of the solid rocks also had been undertaken. Notes were made on the field-maps as to the present state of the land, whether under grass, tillage, etc., and also as to the character of the soil, so far as this could be determined by traverse only.

It was observed that in this district, as in most parts of the United Kingdom, the area under tillage has evidently decreased greatly of late years, while the area of grazing land has correspondingly increased, and is largely occupied by dairy farms, from which a large proportion of the milk-supply of Dublin is drawn.

The greater part of the area in Sheet 112 is an undulating plain of Lower Carboniferous rocks more or less deeply drift-covered, but the southern side includes the northern margin of the Leinster Granite, with strips of the Older Palæozoic rocks fringing the granite on the east and on the west, and in this district the ground becomes mountainous and the drifts more irregularly dispersed. The plain is trenched by the valleys of the Tolka, Liffey and Dodder Rivers discharging into Dublin Bay, while the easterly part of the hilly tract is drained by small streams falling into Killiney Bay. On the north side of Dublin Bay the rugged peninsula of Howth with its attendant islet of Ireland's Eye, composed of the Older Palæozoic rocks, lies within the sheet. The shape of the ground has profoundly influenced the characters and mode of occurrence of the glacial deposits, so that the study of the physiography and of the glacial geology of the district are closely interlinked.

The area surveyed was divided out among the members of the field-staff as follows:—Mr. Kilroe mapped the district extending from the south-west suburbs of Dublin to the southern margin of the sheet, including the coast-line from Merrion through Kingstown to the south side of Killiney Bay (six-inch Sheets 23 and 26), and also an inland tract on the lower slopes of the Dublin Mountains extending westward to Rathfarnham (eastern half of Sheet 22). Mr. McHenry examined the central district (six-inch Sheet 18), including the City of Dublin and its suburbs northward to the Tolka Valley and westward along the Liffey Valley to Chapelizod, with the ground to the southward (western half of Sheet 22) up to the foot of the hills, and westward north of Tallaght to the margin of the map (north-east corner of Sheet 21). Mr. Seymour and Mr. Wright divided between them the northern and western margin of the map from Howth westward

Digitized by Google

beyond Blanchardstown (S. part of six-inch Sheets 13, 14, and 15, with Sheet 16), and thence southward to Clondalkin (E. part of Sheet 17); these officers likewise surveyed the mountainous ground on the south between Glenasmole and Stepaside (north part of six-inch Sheet 25). Mr. Lamplugh mapped a small tract in the extreme south-west corner of the sheet (parts of six-inch Sheets 21 and 24), and also undertook general charge of the field-work, instructing and advising the officers in respect to the mapping, and inspecting the work when done. Mr. Lamplugh, and Staff.

The previous literature relating to the drifts of this district is extensive, the fine coast sections and the high-level shelly gravels of the mountain slopes having received especial attention. In the forthcoming memoir full reference will be made to this literature, and meanwhile it will suffice to mention that among the chief contributors to the subject have been the Rev. Maxwell H. Close, J. Kelly, the Rev. Canon Grainger, G. H. Kinahan, Prof. E. Hull, A. Bell, T. Mellard Reade, Prof. W. J. Sollas, and R. Lloyd Praeger.

In order to make clear certain detailed results to be afterwards recorded, which were obtained severally by the above-mentioned officers, it will be advisable to give first a brief outline of the broader features of the drift deposits of the neighbourhood of Dublin.

From the northern margin of the map up to the foot of the mountains, the prevailing material is a tough dark boulder-clay, highly calcareous, both in the matrix and in the included stones. This boulder-clay represents the crushed material of Carboniferous Limestone and its accompanying shales, but it usually contains also a few fragments of Silurian grit, Old Red Sandstone, and various intrusive rocks transported from beyond the limits of the limestone. Though moulded upon or against the bolder rock-features, it fills up and obliterates all the minor inequalities of the rock-surface, forming smooth gentle slopes descending gradually toward the main drainage hollows of the inland districts and eastward toward the sea. It appears at one time to have obliterated all the minor stream-courses of the district, and also the sharper features of the principal river-valleys, the present streams having in most cases re-excavated channels through the boulder-clay which sometimes coincide with their former rock-channels and sometimes do not. The smooth featureless surface of the boulder-clay usually gives no indication as to the thickness of the drift, the solid rock being in some places within a foot or two of the surface, while in other places it may be buried to a depth of 100 feet or more; it is usually found, however, that the deposit is thickest at the lower level, and thins away toward the crests of the smooth rounded swells which form the minor watersheds of the Carboniferous plain, so that on these crests the rock is often only thinly sprinkled with drift. The limestone also crops out in a few curiously bold bosses along the northern margin of the map,

Digitized by Google

Mr. Lamplugh and Staff.

where massive pale crystalline limestone having the much discussed "knoll-structure" occurs among the thinly-bedded shaly Calp Limestone. Glacial striæ were observed in numerous places beneath this boulder-clay, and these indicate a general movement of the glaciating agent from about N.N.W. to S.S.E. over the plain, *i.e.*, from the interior toward the sea. As will presently appear, however, this direction changes on the eastern flank of the mountains; and both to the northward and southward of the present map the striæ indicate an ice-flow roughly parallel to the present coast-line.

The homogenous character of the boulder-clay is lost as we leave the limestone plain and enter the granite country, owing, in the western part of the district, to the admixture of granitic and other local detritus (which curiously hugs the slope of the hills and never extends beyond a very short distance on the plain), and in the eastern part to the incoming of a boulder-clay of different composition which appears partly to replace and partly to underlie the limestone-clay.

Mr. Lamplugh.

Disconnected patches of stratified drift-material make their appearance here and there over every part of the drift-plain, and evidently represent the local sifting of the ice-borne detritus by flowing water. This local sifting has taken place during the accumulation of some of the boulder-clay as well as in later times. In the former case the assorted material has probably been derived directly from the melting ice, and in the latter from the washing down of the previously deposited clay. It has, therefore, been found possible in most cases to make a rough classification of the gravels according to age, though in places where gravels of different age are conterminous their separation was scarcely practicable.

On the drift-plain north of the Liffey the stratified material occurs chiefly in elliptical mounds or short ridges, sometimes arranged in clusters and sometimes rudely lineated, and often associated with outcrops of the solid rock-floor. Owing to the clayey character of the residual soil formed from the decay of the more or less argillaceous limestone-pebbles which preponderate in the gravels, there is frequently little or no surface indication that these mounds differ in composition from the surrounding boulder-clay tract; but so many open sections of gravel and calcareous sand were observed in them that there can be little doubt these mound-features, where not caused by bosses of solid rock, are nearly always due to the presence of a core of stratified drift, and that in this district there are few or no true "drumlins" of boulder-clay. These mound-gravels may rest either on boulder-clay, or on the solid rock. In three or four instances where sections were exposed, their lower flanks were seen to be enwrapped and covered by the higher portion of the boulder-clay, with a more or less gradual passage downward and inward from the unstratified into the stratified drift. The bedding of the mounds is generally arched in the same direction, though not so steeply as the surface. They present, in short, all the usual

Digitized by Google

"kame-structures," and must be closely associated in age and mode of origin with the continuous esker-ridge south of the Liffey, next to be noticed. Mr. Lamplugh.

The most northerly indications of this esker, in the country examined, appear to be the irregular gravel mounds and ridges seen on both sides of the Liffey Valley near Chapelizod, but the continuous embankment-like ridge sets in at Drimnagh, about a mile further south, and runs southward thence with a sinuous course for nearly three miles, to the Dodder Valley, while its prolongation south of that river is again indicated by broken moundy ground, trending now to the eastward. The characteristic esker-structure is beautifully displayed in the numerous large gravel-pits opened into this ridge. Though usually resting on boulder-clay this esker crosses a low ridge of limestone about mid-way in its course, and the fortunate occurrence of a deep pit at this point reveals new evidence of much interest. It is here seen that the gravel in the middle of the ridge rests upon a battered and water-worn floor of limestone, but that a few yards outward, towards the western side of the esker, the bottom gravel passes into gravelly clay full of scratched stones, resting upon a well-scratched rock-surface.

Here, then, is definite proof that at this point the waters carrying the gravel were at ground-level, and also apparently that they were hemmed in by ice at the margin of the ridge.

In approaching the mountains the drifts show a rapid increase in stratified material, and at the highest levels they usually end off upon the hills of granite and slate in thick irregular masses of sand and gravel, composed of the materials of the limestone-drift mingled with local detritus and with a few far-travelled stones. The presence of shell-fragments in this portion of the drift, at elevations up to 1,200 feet, has been the subject of much discussion, and is usually held to imply a submergence of the land to this extent; but the position, mode of arrangement, and contents of shell-bearing drifts, as well as the general tenour of the physiographical evidence, is quite incompatible with the view that they represent marine deposits; while on the other hand the facts all converge to prove that we are dealing with the marginal phenomena of an ice-sheet.

Excellent sections exhibiting the relationship between the high-level and low-level drifts are exposed in the high river-banks of the Dodder in Glenasmole, and in the glens of the mountain streams which join the Dodder at Rathfarnham. At the edge of the plain these usually show the intercalation of gravel, sand and silt between two boulder-clays, and the rapid thickening of the stratified material, at the expense especially of the upper boulder-clay in passing up the valleys, until finally the upper clay disappears entirely. The gravels then occupy the surface in a moundy belt, overlapping the lower clay and ending off on the slopes or in the high cols of the solid rock. Similar phenomena on a smaller scale are seen on the northern side of the rocky promontory of Howth, where a thick shell-bearing sand and gravel, banked against a rock-slope

Digitized by Google

Mr. Lamplugh.

opposite the mouth of a wide hollow, is seen to fade out laterally between two boulder-clays. Where dominated by steep rock-slopes, the drifts are usually overspread and more or less intermixed with local rubble, which appears to have been washed down the hillsides by rain and floods both during and after the formation of the upper part of the drifts.

Besides the gravels associated, as above described, with the boulder-clay, there are, in several parts of the district, tracts of gravel of later age, but still of considerable antiquity. These gravels overspread the drifts in flat sheets occupying comparatively low and depressed ground, but yet usually outside the confines of the present river valleys. They are clearly associated with the rapid denudation which took place when the land was once more laid bare, but before the streams had re-excavated proper channels and were comparatively unconfined. The largest tract of this kind in the present map lies immediately to the south of Rathfarnham, and represents the gravels suddenly thrown down by the flooded mountain-streams on reaching the foot of the slope. From the gravels of this character to the high-level river gravels there is often but a step, and the latter descend by successively lower terraces to the recent alluvium, as is excellently seen in the valleys of the Dodder and the Liffey. Thus, from the period of deposition of the high-level drifts to the present time, there is clear proof of uninterrupted land conditions, except in a narrow strip along the coast-line where an ancient sea-beach, raised a few feet above present high-tide level, is distinctly marked.

A striking but hitherto neglected peculiarity of the district around the foot of the mountains, is the presence of numerous short, deep, water-cut gorges with precipitous walls, notching across projecting spurs of the granite and slate rocks in positions where, under existing circumstances, no stream could flow. These are now either quite dry or occupied only by a mere trickle of the rainfall-water collected within them. There seems to be no other possible explanation for these gorges than that they were excavated by powerful streams either draining directly across the ice-sheet or representing the overflow from the small lakes held in between the hills on the one side, and the margin of the ice-sheet on the other, after the manner made familiar by the recent geological explorations in Greenland and Spitzbergen.

In the S.W. corner of the map, notches of this kind are conspicuous on the slopes of Slievenabawnoge; on the opposite side of Glenasmole a very fine example, with walls 90-100 feet high, cuts the ridge south of Montpelier House at an elevation of 1,035 feet; others occur on the lower spurs of Three Rock Mountain; and a small but typical example at a lower elevation gashes the low ridge of granite one mile south of Carrickmines.

Advantage may be taken of this opportunity to state, with little hesitation, that the picturesque and much-visited gorges of The Scalp and The Glen of the Downs, lying respectively one mile and seven miles to the southward of the margin of the district at present under examination, may be assigned to the

Digitized by Google

same agency, and that these exhibit the characteristic features of "overflow channels" on the grandest scale. Mr. Lamplugh.

The study of the present river-valleys of the district has yielded some instructive results in regard to its post-glacial denudation. The pre-glacial valleys of the Liffey and the Dodder, within Sheet 112, appear to have coincided in most places with the present valleys, so that these streams have been mainly occupied since glacial times in clearing out the drift-material with which they were choked. Here and there, however, they have swerved from the original channels in the process; as, for example, at Palmerston where the Liffey at its sharp elbow has cut a deep ravine in the Carboniferous Limestone, while there are indications that its drift-filled pre-glacial channel lies a little to the northward of the present river. The southerly tributaries of the Dodder appear also for the most part to be following their old courses; with an occasional striking divergence, as where the little stream from Piperstown swings away from its drift-filled depression and plunges through a deep chasm across the spur of slate to join the Dodder near Fort Bridge. But in the irregular ground between the southern shore of Dublin Bay and the mountains, the old drainage system is much confused, and the streams have carved new channels for themselves in the granite in many places. North of the Liffey also, the Tolka, for the greater part of its course in Sheet 112, occupies a new channel, cut through the drift into the limestone, and no definite evidence is yet forthcoming as to its pre-glacial course.

The general conclusion to be drawn from the post-glacial work of the streams is that a comparatively long period must have passed since the recession of the ice from the district.

The more important of the local observations of the several members of the Irish staff, with some individual conclusions which have not found place in the preceding *Summary* will now be given.

In the south-western corner of the district, just beyond the margin of Sheet 112, Mr. Lamplugh found that the projecting spur of the mountains lying west of Glenasmole, composed of the slate with igneous intrusions, was in part capped, to a depth exceeding 12 feet in one section, by stiff calcareous till containing many striated boulders of Carboniferous Limestone. This boulder-clay reaches an elevation of over 1,100 feet above O.D., although the steep sides of the spur are free from drift. This is the greatest altitude to which the limestone boulder-clay, as distinguished from the stratified drift, has yet been traced. As the high-level drift usually consists of gravel, sand and local rock-rubble, which many observers hesitate to recognise as glacier-borne, the presence at this altitude of typical boulder-clay which would be generally acknowledged as the direct product of land-ice, is of importance in proving that the ice-sheet must have been sufficiently thick to reach the level of the highest gravels.

In the south-eastern part of the sheet the tract of 32·2 square miles, surveyed by Mr. Kilroe, is mainly underlain by granite, Mr. Kilroe.

Digitized by Google

Mr. Kilroe.

over which the drifts are somewhat irregularly distributed. The following useful table compiled by this officer will serve to show the relative area of the various superficial deposits and of the solid rock :—

	Total area.	Rock.	Local Drift.	Limestone Boulder-clay.	Glacial Sand and Gravel.	Late Glacial Flood-gravel.	Old River Alluvium.	Recent Alluvium.	Intake.
In Six-inch	Acres.	Acres.	Acres	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Sheet 22	7,686	461	562	5,976	69	349	128	141	..
„ 23	7,592	670	650	5,866	126	96	29	81	74
„ 26	5,330	678	859	3,376	111	25	58	223	–
Total in Sq. Miles.	32·2	2·83	3·23	23·78	·48	·73	·33	·69	·11

With regard to the area shown as bare rock, however, Mr. Kilroe remarks that even here there is usually a sprinkling of grit and limestone pebbles, and that where the rock-surface is uneven, the "pockets" contain transported drift, while a thin, locally-formed clayey rubble occurs in many places where it is necessary to map the ground as rock. The "dry gaps" in the granite south of Carrickmines, to which reference has previously been made, are thus described:—"Two of these cut across the rock-ridge which is separated from the mountains by Kiltiernan valley. They run parallel to each other in a S.E. direction, and in the lowest part present just a noticeable slope towards the south. The more easterly, known as the Dingle Glen, is a steep-sided ravine with a strikingly fresh eastern face of rock, in parts almost vertical, and throughout strewn with recent granite talus. The ground above, sloping gently towards the gap on both sides, is almost bare rock, except on the S.W. side, where it carries a thin coating of local drift. The bottom of the glen, about 50 feet from the crest, is covered with recent alluvium, and near its exit southward occurs a deposit of clay with boulders of limestone as well as granite. That the very recently-formed appearance has been given to this glen by the rush of water attendant upon the melting of the ice sheet there can be little doubt. The deposit of boulder-clay at the southern exit, however, seems to me to preclude the conception that the glen owes its origin to any material extent to glacial denudation. The second glen, Glenamuck, is not so striking a feature, though the origin of both is in all probability identical; and at each end rests a covering of boulder-clay containing grit, black chert and other travelled pebbles, mingled with boulders and talus blocks of granite. Another short gully in the granite near Sandyford, of somewhat different character, must have been in existence before the close of the Glacial Period, as one of its rocky slopes is glaciated."

Digitized by Google

In examining the frequently-described cliff-sections south of Killiney, Mr. Kilroe paid close attention to the proposed subdivision of these drifts into "Upper Boulder-clay," "Middle Glacial Sand and Gravel," and "Lower Boulder-clay," but found that these divisions were too changeable and impersistent to be used in mapping the deposits. He observed that bands of more or less stony clay and silt, with all the characteristics of boulder-clay are intercalated and "dovetailed" with the layers of sand and gravel; and found reason to doubt "whether the lowest visible boulder-clay in the whole extended section constitutes the original base of the sand and gravel deposit, if indeed a 'basement clay' in this sense have any existence here." The lowest visible band of clay, however, presents some peculiar characteristics. Though mostly dark grey or slate coloured, some portions of the clay are purple, passing into red, in such a manner as to suggest that the red colouration is due to progressive weathering. "A remarkable feature of the red boulder-clay at one point is, that it contains large irregular *masses* of purple boulder-clay, with sharply-defined outlines—true boulders, in some cases sharply fractured, the gaping cracks being filled with sand, gravel or clay from the surrounding matrix. These clay-boulders show lamination or a flaky structure, and are easily distinguishable from the surrounding red clay when once noticed, not only by a slight difference of colouring, but in this also, that the masses are highly calcareous and the containing clay not so. The stony contents of both—chiefly green grit and slate and granite fragments—are alike, from which, as well as from the fact that some of the enclosed masses show fringes coloured red around cores of purple clay, it is inferred that the red clay is a more highly oxidised form of the purple material. The alteration, however, is not usually by gradual encroachment of oxidation and decalcification from without, but through the matrix having undergone vicissitudes, re-arrangement, &c., not experienced by the included masses." Mr. Kilroe.

Mr. Kilroe considers that these remarkable clay-boulders afford material aid in unravelling the history and mode of deposition of the series. He finds that the peculiar boulder-clay which is extensively dug for brick- and tile-making at Kill of the Grange, $2\frac{1}{4}$ miles inland, W.N.W. of Killiney (fully described by Professor Sollas, and Mr. R. L. Praeger in *Irish Naturalist*, Dec. 1895) is "almost if not quite identical with, and strikingly similar to that which composes the included masses of the Killiney section," and therefore concludes "there can be little room to doubt that the masses have been severed from a deposit similar in every way to that at Kill . . . This being admitted, the conclusion is inevitable that the Kill of the Grange deposit dates further back, in the series of glacial episodes, than the Killiney sands and gravels, and is anterior to the *layers* of boulder-clay interstratified with them; and this leads to the further inference that the deposit in question is a true Lower Boulder-clay."

With regard to the sands and gravels of the Killiney section, which, as previous observers have noticed, are steeply tilted in one part of the section, and almost horizontal in another part,

Digitized by Google

Mr. Kilroe.

Mr. Kilroe has noticed some curious features indicating the disturbance and breaking up of the deposits when frozen. "Thus, fissures were formed in stratified sand and gravel, and filled with dyke-like tongues of gravel or of clay, a remarkable example of which is to be seen in the sea-cliff at the railway station at Killiney. What is so remarkable in this instance is that while the clay-tongue is obviously stratified and the stratification is further marked by an included layer of gravel, the fissure seems to have been filled from beneath, a circumstance difficult to explain." In another place it was found that the red boulder-clay above described had been curiously invaded by coarse unstratified gravel or shingle, which had filled a gap about eight feet wide: the margins of the gap were vertical, and sharply jagged and rent, the shingle passing insensibly upward into stratified gravel which was in turn capped by an upper sandy clay. These and kindred facts lead Mr. Kilroe "to picture the phenomena attendant upon the decline of glacial conditions in this (Killiney) district as follows:—

1st.—A lower boulder-clay, broken up and denuded in connection with the formation of—
2nd.—Sands, gravels and boulder-clay layers.
3rd.—Breaking up of boulder-clay layers, and rearrangement of gravels.
4th.—Pipes, guts, or pot-holes in 3rd series.
5th.—Continuation of sand and gravel deposit.
6th.—Upper clay.

"Perhaps the best way of accounting for the sequence of phenomena, thus shown to be in some sense recognisable, is, by conceiving that, following the deposition of the lower boulder-clay, and during the melting of the great sheet of land-ice, there were deluges which carried off the finer matter (clay, silt, &c.), and deposited layers of stratified gravels, alternating with unassorted materials now forming boulder-clay; and, possibly, also temporarily-formed lakes with frozen margins, in which were laid down the finer sediments, into which stones were occasionally dropped from small floating ice-rafts or bergs." The detached clay masses are considered to have been torn from steep banks of frozen clay, eroded by these floods. Mr. Kilroe is opposed to the view that the recurrence of boulder-clay among the sand and gravel is here attributable to alternating advances and retrocession of the margin of the ice sheet.

The presence of marine shells, mostly fragmentary, which are sparsely scattered through both the lower boulder-clay and the gravels at Killiney, has been noted by many previous observers. Mr. Kilroe considers that the boulder-clay should be regarded as the source of these shells, "and, inferentially, that it, or the materials composing it, were originally laid down on the sea-floor and subsequently pushed up over the land"; and that, from the denudation of this clay, the shells in the gravels have been derived.

The upper boulder-clay of the Killiney section is yellowish and sandy, and in some places contains numerous large blocks of the local granite. It is usually greatly decalcified and oxidised, and,

Digitized by Google

near Killiney Station, rests upon the truncated edges of sand and gravel beds, here highly inclined. "A short distance south of the station this clay seems to attain a thickness of some 30 feet, which is quite unusual in the entire section or elsewhere in the district. It is probable, therefore, that the top clay merges imperceptibly into one of the layers of the boulder-clay (or several layers combined) which are included in the sand and gravel series; for when these layers occur near the top of the section, they are so highly oxidised and decalcified as to become indistinguishable from the clay which caps the gravels, and for this reason is entitled to the appellation of 'Upper Boulder-clay.'" At many other places in the district a boulder-clay up to 10 or 12 feet in thickness was seen to overlie gravels, but whether this represents the upper clay of the Killiney section could not be determined. Mr. Kilroe.

After mentioning and stating objections to the various hypotheses which have been put forward to explain the Irish drifts, and especially their included marine shells and foraminifera in certain localities, Mr. Kilroe writes as follows:—

"Almost the only remaining probable hypothesis is that the materials of the Kill of the Grange clay, and similar clay at other points, has, as already mentioned, been pushed upward as *moraine profonde* from the Irish Sea bed, and if this view be accepted, it at once accounts for the fossil- and stone- contents of the clay and subsequently-deposited gravels. The great obstacle to the acceptance of that hypothesis, of course, is the prevalence of easterly striation—the only direction now noticeable. In its favour, however, it may be mentioned that in coming from the westward it could not have carried the materials of the Kill of the Grange clay; while these materials are exactly such as could have been accumulated on the sea-floor by glaciers descending from the marl plains of Antrim and Down, on the west, and those of the Solway region and Cheshire, probably, on the east, as well as from the glens of Down, Cumberland and Wales, during the approaching climax of glacial conditions. The objection to the material having been subsequently pushed up over Irish land is not insuperable if we conceive that such an accumulation of ice and *névé* occurred in the Cumbro-Cambrian region as, after filling up the Irish Sea, temporarily overmastered any ice-flow coming at the time from Central Ireland, and dragged the sea deposits inward over the present Irish coast line. This westerly flow from Cumberland would become reversed as the Irish ice-system grew, and would unite with an ice-stream flowing southward along the channel, as would also the new easterly ice-flow from Central Ireland. This last, continuing probably for a much longer period than that during which the westerly flow over-rode Irish land, would have obliterated all trace of the latter, except possibly in the spots where the lower boulder-clay occurs, where, however, striæ have not been found."

Agricultural Notes.—The prevalence of limestone detritus profoundly affects the character of most of the ground in this

Digitized by Google

Mr. Kilroe. sheet. The fertility of the soils derived therefrom is manifest in the luxuriant park-timber and hedge-rows, the choice and succulent herbage, which deck the lower portions of the area. The boulder-clay soils and those covering the various deposits of limestone gravels are mostly rich brown loams, which, though in many cases highly retentive, do not manifest great need of artificial drainage.

The alluvial deposits consist of, or yield on weathering, rich sandy loams, bearing a luxuriant herbage, or equally luxuriant crops where tilled, all of which indicate the beneficial effects of occasional saturations of the soils with lime-charged waters, or of top-dressings with flood-silts drawn from limestone, occurring either as solid rock or drifted detritus.

Skirting the small areas of granite in the lower ground, and on the hill slopes below where the granite, slate, &c. protrude above the drift, the soils and sub-soils show a quantity of locally derived material, replacing or concealing the limestone boulder-clays. The soils in those places are poor in comparison with those derived from the limestone detritus, and bear, when not manured, a coarse, unpalatable herbage.

Several samples of soils and sub-soils were taken during the progress of the Survey, and are undergoing examination, the results of which will appear in the Memoir.

Mr. McHenry The area of forty-one square miles surveyed by Mr. McHenry lay almost entirely on the plain in the central part of Sheet 112, and therefore was mainly overspread by the limestone-boulder-clay, though diversified, as already described, in the western part by a fine esker-ridge, and by the valleys of the Liffey and Dodder with their post-glacial fluviatile deposits, and also by the low raised beach along its seaward margin. The central part of the city of Dublin is placed on this raised beach, or on the river-deltas conterminous with it, but the higher parts of the city, with most of its suburbs, are built upon the gentle slopes of boulder-clay which border these flats. Although the boulder-clay over the greater parts of the area is of the dark blue limestone-type, there is a marked change of character in certain parts of the mass as we approach the southern margin of the Carboniferous Limestone tract. Thus, in several good sections in the bank of the tributary streams on the southern side of the Dodder Valley between Rathfarnham and Firhouse, a dull purple tenacious clay is exposed, resembling that of the Kill of the Grange brick-pits (above described by Mr. Kilroe). This clay always contains a few fragmentary shells, just as at Kill of the Grange and Killiney, whereas no shells have been found in the normal limestone clay. In one of the stream-sections it was traced southward to Rockbrook, nearly three miles south of the Dodder, sometimes underlying bands of the normal limestone-clay; and it is highly suggestive of the close association of this clay with the shelly stratified drift, that we should find some of the principal exposures of the high-level shell-bearing gravels on the hill-slopes within a mile to the S. and S.E. of this place, and that at Larch Hill a patch of clay of similar character should be actually included in the gravels.

Digitized by Google

Where the Dodder Valley cuts into the esker-ridge some fine sections are exposed along the river-banks. Mr. McHenry

At this point Mr. McHenry observes that the material of the esker has been entirely derived from the same source as the boulder-clay, the included stones being identical in character, and both showing a notable absence of the Leinster granite, although this local granite is very conspicuous in the late-glacial flood-gravels and subsequent high-level gravels of the Dodder, which rest on eroded surfaces of the esker-gravels in these sections.

Until the investigation has been carried beyond the limits of the present area there is room for uncertainty whether the current which deposited the gravel-ridge flowed northward or southward, but the probability is that it took the latter direction. The occurrence of a water-worn limestone surface beneath the esker, which has been previously mentioned (p. 187), is described by Mr. McHenry as follows:—

"There can be little doubt as to the origin of these gravels and sands. Unquestionably they are due to ice-rivers that flowed both on, in, and in many cases under the ice-sheet. In some cases these ice-rivers cut down through whatever slight covering of boulder-clay there may have been deposited on the solid rock, and washed off the original striæ. An instance of this was noticed in the quarry on the west side of the road leading from Green Hills northward, where 20 to 30 feet of gravel is seen resting directly on the Calp limestone, while in the north end of the quarry a thin stratum of boulder-clay rests on the still striated rock-surface, the sand and gravel of the esker resting on the boulder-clay."

With regard to the Late-glacial Flood-gravels, of which several small tracts were surveyed by him, Mr. McHenry remarks that these bear a close resemblance to the river-gravels both in composition and arrangement though differing in their position in respect to the existing valleys. In most of the places where they occur, both deposits have been extensively worked for building purposes and for pathway material.

The deltas formed where the principal streams open out upon the Raised Beach are necessarily shown on the one-inch map as forming part of this Beach, though sometimes rising slightly above its usual level. They are thus described by Mr. McHenry:—

"Along the shore where the Tolka, the Liffey, and the Dodder enter the sea, extensive fan-shaped deposits of gravel and sand have been laid down. Many extensive openings in them can be seen, the best being those now worked in the vicinity of the main-road to Blackrock, east of the Dodder. For its size, the Dodder appears to have deposited by far the greater proportion of these delta-gravels, this being no doubt due to its rapid fall from the Dublin Hills, causing more violent torrents in early post-glacial times, and to the enormous quantity of glacial material with which its ancient channel was choked.

Digitized by Google

Mr. McHenry "There is a well-marked feature on both sides of the Liffey which defines the boundary of its river-deposits with the underlying boulder-clay. In all cases, during the excavations for main-drainage purposes, river-gravel was found to exist within the limit of this feature. In almost every instance the river-gravel rests directly upon the boulder-clay, but in a few cases it rests directly on the Carboniferous Limestone, as at the bottom of the new Hawkins Street shaft of the tunnel under the Liffey."

Mr. Seymour. The mountainous ground surveyed by Mr. Seymour on the southern margin of Sheet 112 included the summits of Three Rock (1,479 ft.) and Two Rock (1,699 ft.) Mountains; and Fairy Castle (1,763 ft.) and the lower hills to the westward, with the intervening valleys.

"The deposits of drift are chiefly confined to the valleys, the hilly ground being practically bare granite with a scanty covering of heather and peat. In the Larch Hill and Ticknock valleys, however, the boulder-clay runs up to heights of 1,090 ft. and 950 ft. respectively, the section in the former being 8–10 ft. thick at this elevation and full of striated limestone pebbles and boulders. . . . Kilmashogue Mountain (1,339 ft.) is almost entirely surrounded by gravel, and the outer boundary of this probably represents the line of a retreating glacier, between the front of which and the mountain slope, the washed morainic material would be deposited as gravel. Some of the steep lower slopes, on which no drift has lodged, are thickly strewn with large boulders of granite, and similar boulders frequently occur in the gravels, especially in their upper part. . . . South of Kilmashogue is another area of gravels, moundy in places, and reaching a maximum elevation of over 1,300 feet, which have long been noted for the numerous shell-fragments they contain."

A dry gap cutting the ridge on the east side of the Ticknock valley, similar to those at lower levels to the eastward, previously described, is remarked by Mr. Seymour to lie in an almost direct line with the great Montpelier Gap to the westward (in Mr. Wright's ground) and with another still farther west. To explain the much lower elevation attained by the drift on the mountain slopes outside the valleys, Mr. Seymour suggests that the western valleys being of gentle slope without any sharp rise, and lying also in the direction of the ice-flow, as indicated by the striæ, afforded an easy ascent for the drift-laden lower part of the ice, which could not rise upon the bluff slopes of the hill-shoulders.

The tract examined by Mr. Seymour in the N.W. corner of the sheet, forming part of the Carboniferous Limestone plain, is chiefly overspread with limestone-boulder-clay, with some minor kame-like mounds of gravel and protruding ridges of bare or nearly bare rock. The chief interest in this ground centres in the Liffey Valley, which trenches the plain and reveals many good sections in natural and artificial exposures on its steep slopes. It is in this tract that, as previously mentioned, the Liffey apparently diverges from its pre-glacial valley, and cuts a short looped cañon in the solid rock. Near this place the gravelly mounds which are believed to represent the northward

Digitized by Google

prolongation of the Green Hills Esker, are intercepted by the present valley, and the diversion of the river may possibly have been connected with this circumstance. The easterly portion of the buried pre-glacial channel appears to be filled up chiefly with boulder-clay, as indicated in a deep lateral ravine and in well-borings in the S.W part of Phœnix Park; but in the western portion there is a thick mass of gravel, which is well seen in pits in the valley below Knockmaroon Lodge. In one of these pits, close to the ferry, numerous shell-fragments were found, associated as usual with far-travelled stones including the Ailsa Craig rock, and with streaks of brown clay. The drifts of the surrounding country appear to be devoid of shells, and no previous record of their occurrence in the Liffey valley is known. Mr. Seymour.

The mapping of the drifts on the peninsula of Howth was undertaken at the beginning of the field-season by Mr. Seymour and Mr. Wright, under the personal guidance of Mr. Lamplugh. It was found that the limestone-clay had practically enwrapped the lower slopes of the hill, though now in part stripped off by later erosion. The curious manner in which this material is "plastered" against the slopes has frequently attracted attention. The summit, however, is principally bare rock, with narrow "tongues" of drift in the hollows between the bosses of quartzite. These bosses are frequently ice-scored, especially on the quartz-veins, where the striæ are so fine that they become visible only after the application of some such colouring material as scraped lead-pencil to the smooth greasy-feeling white surface. The striæ indicate a general movement of the glaciating agent from about W. 30 N., but swing round the shoulders of the hill, where the ice-current has been deflected. The limestone-clay in the hollows is sometimes covered by a few feet of local detritus, probably in part glacial and in part a later storm-wash, and in some places this material alone is present. Mr. Seymour and Mr. Wright.

The thick mass of gravel and sand banked against the northern side of the hill at the village of Howth is one of the well-known shell-bearing drift-deposits of the Dublin district, and similar shell fragments also occur sparingly in the patches of boulder-clay on the eastern and southern slopes of the peninsula. The gravels at Howth attain their maximum development opposite a broad depression in the solid rocks, which runs south-eastward nearly across the headland, and they appear to be intimately related to this feature. To the eastward and westward of this hollow the stratified material diminishes rapidly in quantity and in texture, until it appears finally to thin out between an upper and lower band of boulder-clay.

In discussing the upper part of the boulder-clay of these sections Mr. Seymour remarks that it resembles the upper clay which he observed to be similarly associated with gravels in the other areas mapped by him, being less compact than the lower clay and generally found at the foot of more or less steep ascents. "It is almost certainly derived from material either in ice (englacial), or attached to the soles of icebergs: in the first case the material being let down *in situ* by the gradual melting of the

Digitized by Google

Mr. Seymour and Mr. Wright.

ice, and in the second case dropped from melting bergs in lakes." The second explanation appears to him to be the more probable, as the upper clay within the area surveyed by him occurred in places where temporary lakes were likely to be formed during the recession of the ice.

The supposed high-level raised beach near the Bailey Lighthouse, mentioned in the *Survey Memoir* (p. 67), proves to be a "kitchen-midden," containing only edible shells, broken bones of domestic animals, and other indications of artificial accumulation. The only trace of post-glacial marine submergence in this, as in other parts of the district, is the conspicuous Raised Beach of shingle and sand with recent shells, rising 10 to 20 feet above present sea level, which forms the low spit connecting Howth with the mainland. On the rocky outer shores of the headland and of Ireland's Eye, this beach is indicated in places by an eroded rock-shelf and by ancient caves. A cemented mass of old beach-material was observed in one of these caves on Ireland's Eye, adhering to the rock-walls at the usual level of the Raised Beach.

On the mainland west of Howth, the plain of boulder-clay is deeply furrowed by broad drainage hollows, regarding which Mr. Seymour notes: "none of the streamlets now flowing in them could possibly produce such features; they are all 'mis-fits,' and the principal work of erosion must be attributed to a time after the glacial period, when much larger streams flowed through these valleys."

Mr. Wright.

The area surveyed by Mr. Wright in the northern part of Sheet 112, while mainly overspread with the limestone-boulder-clay, was broken in places by outcrops of the solid limestone, and by irregular mounds and short esker-like ridges of stratified drift, the latter being associated, in the vicinity of the Tolka river, with gravelly flats. That these stratified drifts were directly of glacial origin was frequently evident from the manner in which they merged gradually into clayey unstratified material full of scratched stones, which was inseparable from the normal boulder-clay of the district.

In the mountainous ground examined by Mr. Wright in the south-western part of Sheet 112 the drifts were much more complicated, and stratified material was much more abundant. Gravelly deposits, composed principally of limestone, but often with a plentiful admixture of the local granite, and with a few far-transported stones, including Chalk flints, Old Red conglomerate, Silurian grit, and occasionally the Ailsa Craig rock, and where unweathered, with shell-fragments, formed moundy ground on the slopes of the hills up to the 1,250 ft. contour. In descending the slopes these gravels appear usually to pass beneath an upper boulder-clay, though the sections are rarely sufficiently continuous to show this relationship clearly. From one of the high-level gravel pits at Larch Hill no less than forty-two species of shells have been obtained by Mr. Hinch, a persevering amateur student of these shelly deposits.

Digitized by Google

The fine high-level notch in the solid rock on the southern side of Montpelier Hill, to which reference was made in the introductory part of this report, is described by Mr. Wright as follows:— Mr. Wright.

"This remarkably steep gap or pass, which is 530 yards long, connects the valleys of Killakee and Glenasmole. Its sides are strewn with blocks of granite, which form a talus at the base, and their slope varies from 20°—35°. The height of the summit is 1035 feet, but it is probably raised considerably above its original height by the falling in of *débris* from the sides. The gap is almost dry, there being only two small rivulets trickling, one from each end, in opposite directions, that on the west being soon joined by a larger stream from the moorland above.

"The gravels associated with this gap form a continuous deposit, lying between the 800 and 1250 ft. contours, which may be roughly divided into an upper and a lower series. The upper series forms a thin covering, with scattered mounds, on the moor overlooking the gap on the south and on Montpelier Hill on the north. The lower series consists of two mounds, one on each side of the valley at the westerly end of the gap. At Ann Mount, in Glenasmole, the gravels also occur at two levels, but the upper level in this case is the same as the lower one in the Montpelier Valley."

II. MAPS PUBLISHED.

The following is a list of the revised one-inch maps issued by the Geological Survey of Ireland during the past year:—

Sheets Nos. 46, 61, 67, 79, 115, 117, 118, 125, 126, 127, 134, 135, 143.

The revisions are almost wholly confined to the Ordovician and Silurian Rocks.

Digitized by Google

APPENDIX A.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH FOSSIL PHYLLOCARIDA preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7509] correspond to the number in the Museum Register.

The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Geol. Mag.: The Geological Magazine, London.

Caryocaris Marrii, Hicks.
Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., f. 16, p. 92.
Arenig. [7509] Skiddaw, Cumberland.

Caryocaris Wrightii, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., figs. 11, 12, p. 89.
Skiddaw Slates. [7508, 7509] Skiddaw.

Ceratiocaris aptychoides, *vide* **Dithyrocaris ?**

Ceratiocaris canaliculata, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 3, p. 32.
Upper Ludlow. [7481] Whitecliff, Ludlow.

Ceratiocaris cassia, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 7 *c–e*, p. 58.
Lower Ludlow. [7451] Trippleton, Leintwardine.

Digitized by Google

Ceratiocaris cassioides, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 6, p. 59.
Lower Ludlow. [7480] Leintwardine, Shropshire.

Ceratiocaris gigas (Salter, M. S.), Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., f. 1, p. 24.
Lower Ludlow. [7452] Danefield, Kington, Herefordshire.

Ceratiocaris halliana, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. ii., figs. 1–4, p. 26.
Lower Ludlow. [7453–7456] Church Hill, Leintwardine and Bow Bridge, Ludlow.

Ceratiocaris leptodactylus (M'Coy).
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vi., figs. 6–9, p. 14.
Wenlock Shale (Coniston Grit). [7459, 7855-7857] Helm Knot, Dent, Yorkshire.

Ceratiocaris longa, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 5, p. 43.
Lower Ludlow. [7468] Leintwardine.

Ceratiocaris minuta ? Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 10, p. 47.
Lower Ludlow. [7478] Leintwardine.

Ceratiocaris Murchisoni (Agassiz).
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., figs. 4, 7, p. 16.
Lower Ludlow. [7473, 7476] Leintwardine.

Ceratiocaris Murchisoni (Agassiz). **T.**
H. Woodward, Geol. Mag., 1866, pl. x., f. 9, p. 203. Refigured as **Ceratiocaris tyrannus**: Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vi., f. 11, p. 20.
Wenlock Shale (Coniston Grit). [7472] Casterton Low Fell, Kirkby Lonsdale.

Ceratiocaris papilio, Salter. **T.**
J. W. Salter, Ann. Mag. Nat. Hist., vol. v., 1860, p. 154, f. 1.
Lower Ludlow. [7479] Logan Water, Lesmahagow.

Ceratiocaris reticosa, Jones and Woodward. **T**
Jones and Woodward, Geol. Mag., 1895, pl. xv., f. 1 *a*, *b*, p. 539.
Ludlow. [4435] Locality ?

Ceratiocaris robusta, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. x., f. 10, p. 44.
Lower Ludlow. [7471] Leintwardine.

Ceratiocaris salteriana, Jones and Woodward. **T**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 1 *a*, *b*, p. 55.
Lower Ludlow. [7477] Bow Bridge, Ludlow.

Ceratiocaris solenoides, M'Coy.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 9 *a*, *b*, p. 52.
Upper Ludlow. [7458 Benson Knot, Kendal.

Digitized by Google

Ceratiocaris stygia, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 3, p. 38.
Lower Ludlow. [7469] Leintwardine.

Ceratiocaris tyrannus (Salter, M. S.), Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., figs. 2, 3, 5, 8, p. 22. (See also *C. murchisoni*.)
Lower Ludlow. [7474, 7475] Leintwardine.

Dictyocaris Ramsayi, Salter. T.
J. W. Salter, M. G. S., Edinburgh, 1861, pl. ii., f. 20, p. 133.
Salter and Woodward, Chart Foss. Crust., 1865, p. 17.
Upper Silurian. [7483] North Esk Reservoir, Carlops.

Dithyrocaris Colei, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., figs. 1–5, p. 314.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiii., figs. 2–5; pl. xxiv., figs. 2, 4, p. 163.
Carboniferous Shales. [6261–6263, 6265] Clogher, Tyrone.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 5, p. 168.
Carboniferous Shales. [6260] Clogher, Tyrone.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., f. 6, p. 315.
H. Woodward, Geol. Mag., 1865, pl. xi., f. 8, p. 401.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., f. 44, p. 194.
Carboniferous Shales. [6264] Co. Derry.

Dithyrocaris orbicularis, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 316.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., f. 3, p. 168.
Lower Carboniferous. [6266] White Water River, Co. Derry.

Dithyrocaris testudinea (Scouler).
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xix., f. 9, p. 145.
Lower Carboniferous. [6268] Glasgow Coalfield.

Dithyrocaris tricornis (Scouler).
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 2 *a–c*, p. 170.
Lower Carboniferous. [7519] East Kilbride, Lanarkshire.

Dithyrocaris ? aptychoides, Salter. T.
J. W. Salter, Q. J. G. S., vol. viii., 1852, pl. xxi., f. 10, p. 391. Described as **Ceratiocaris aptychoides**, J. W. Salter, Ann. Mag. Nat. Hist., vol. v., 1860, p. 161; and as **Peltocaris aptychoides**, Salter, Q. J. G. S., vol. xix., 1863, p. 88 (text figure); Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xvi., f. 3, p. 113.
Llandeilo Flags. [7507] Duff Kennel, Dumfriesshire.

Emmelezoe crassistriata, Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 3, p. 70.
Upper Ludlow. [7457] Combe Wood, Presteign.

Emmelezoe maccoyana, Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii, f. 2, p. 71.
Lower Ludlow. [7470] Leintwardine.

Digitized by Google

Hymenocaris vermicauda, Salter. **T.**

J. W. Salter, M. G. S., North Wales, 1866, pl. ii., figs. 1, 2, p. 293.
Lower Lingula Flags. [7502] Penmorfa, Tremadoc.

J. W. Salter, M. G. S., North Wales, 1866, pl. v., f. 25, p. 293.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiii., f. 9, p. 74.
Lower Lingula Flags. [7503] Moel-y-gest, Tremadoc.

Hymenocaris vermicauda, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiii., figs. 8, 13, p. 74.
Lingula Flags. [7505, 7504] Portmadoc.

Hymenocaris vermicauda ? (tracks of).

J. W. Salter, Q. J. G. S., vol. x., 1853, p. 210. (Text figure.)

J. W. Salter, M. G. S., North Wales, 1866, pl. i., p. 294.
Lower Lingula Flags. [7520] Tremadoc, N Wales.

Lingulocaris lingulæcomes, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., f. 4, p. 81.
Upper Llandeilo. [7510] Builth.

Peltocaris anatina, Jones and Woodward.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xvi., f. 4, p. 114.
Llandeilo Flags. [7506] Moffat ?

Peltocaris aptychoides, *vide* **Dithyrocaris** ?

Peltocaris ? (tracks of).

J. W. Salter, Q. J. G. S., vol. xix., 1863, p. 94. (Text figure.)
Llandeilo Flags. [7521] Wilmington Dingle, Chirbury, Salop.

Salterina [Salterella] pholadiformis (Salter, M. S.), Jones and Woodward. **T.**

Jones and Woodward, Geol. Mag., 1888, p. 453. (Text figure.)
Lower Limestone Shales. [7518] Berwick-on-Tweed.

Digitized by Google

APPENDIX B.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH PALÆOZOIC ECHINODERMATA preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7009] correspond to the number in the Museum Register.

The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.

Pal. Foss.: Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, 1841.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Geol. Mag.: The Geological Magazine, London.

CYSTIDEA.

Caryocystites granatum (Wahlenberg).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 4, p. 512.
Caradoc. [7406] Rhiwlas, Bala.

Caryocystites Litchi, Forbes.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 2 *a–c*, p. 514. Re-figured as **Sphæronites Litchi**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 3 ? 4, p. 286. (Figs. 3 and 4 *c* referred to *S. munitus*.)
Caradoc. [7431] Sholeshook, Haverfordwest.

Caryocystites ? munitus, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 3 *a*, *b*, p. 515. Re-figured as **Sphæronites munitus**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 5, p. 285.
Caradoc. [7429] Rhiwlas, Bala.

Caryocystites pyriformis, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 1 *a–d*, p. 515. Re-figured as **Sphæronites pyriformis**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 1, 2, p. 285.
Caradoc. [7432] Rhiwlas, Bala.

Digitized by Google

Echinocystites pomum, W. Thomson. T.
Wyville Thomson, Edin. New Phil. Journ., N. S., vol. xiii., 1861, pl. i., f. 3, p. 109.
Lower Ludlow. [7385] Leintwardine.

Echinoencrinites armatus, Forbes. T.
E. Forbes, Mem. Geol. Survey, vol. ii., pt. 2, 1848, pl. xviii., figs. 1-6, 11-13; pl. xix., figs. 1, 4, 6, p. 507.
Wenlock Limestone. [7381-4] Walsall.

Echinoencrinites baccatus, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xvii., figs. 1, 3, 4, p. 506.
Wenlock Limestone. [7380] Walsall.

Echinosphærites arachnoideus, *vide* **Sphæronites.**

Hemicosmites oblongus, (Pander).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., f. 6, p. 511.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 11, p. 288.
Caradoc. [7426] Sholeshook, Haverfordwest.

Hemicosmites pyriformis, v. Buch.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., figs. 2-5, p. 511. Refigured as **H. rugatus**, Forbes: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 12, p. 288.
Caradoc. [7421, 7422] Gt. Cresswell, St. Clare; Sholeshook.

Hemicosmites rugatus, *vide* **H. pyriformis.**

Pleurocystites Rugeri, Salter. T.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 5, p. 288.
Caradoc. [7434] Blaen-y-cwm, nr. Llandovery.

Sphæronites arachnoideus, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 4, p. 518. Refigured as **Echinosphærites**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 8, p. 287.
Caradoc. [7405] Sholeshook, Haverfordwest.

Sphæronites aurantium (Gyllenhal).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 1 *a*, *b*, p. 516. Fig. 1 *b* refigured as **S. stelluliferus**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 6, p. 287.
Caradoc. [7428] Sholeshook, Haverfordwest.

Sphæronites Litchi, *vide* **Caryocystites.**

Sphæronites munitus ? Forbes.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 3, 4 *c*, p. 286.
Caradoc. (See also *Caryocystites.*) [7430] Sholeshook, Pembrokeshire.

Sphæronites ? punctatus, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 2 *a*, *b*, p. 518.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 7, p. 286.
Caradoc. [7433] Rhiwlas, Bala.

Sphæronites pyriformis, *vide* **Caryocystites.**

Sphæronites stelluliferus, *vide* **S. aurantium.**

Digitized by Google

Crinoidea.

Actinocrinites amphora, (Goldfuss).
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., figs. 4 *a*, *b*, 5 *a*, *b* p. 347.
Carboniferous Limestone. [7615] Cleenish, Tonyloman, Fermanagh.

Actinocrinus ? Batheri, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., 1898, vol. lii., pl. xxxii., figs. 2, 2 *a*, *b*, 3, 3 *a*, *b*, p. 222.
Upper Devonian (Marwood Beds). [7145, 7146] Braunton, North Devon.

Actinocrinites decadactylus ? Goldfuss.
J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 349.
Carboniferous Limestone. [7629] Stewartstown, Tyrone.

Actinocrinites icosidactylus, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 7, p. 348.
Carboniferous Limestone. [7628] Hook, Wexford.

Actinocrinus Porteri, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., figs. 1, 1 *a* 2, 5 ; pl. xxxii., f. 1, p. 220.
Upper Devonian. [7138–7141] North Devon.

Actinocrinites ? retiarius, Phillips. T.
R. I. Murchison, "Silurian System," pt. 2, 1837, pl. xvii., f. 7, p. 674.
Wenlock Limestone. [7379] Dudley.

Adelocrinus hystrix, Phillips. T.
J. Phillips, Pal. Foss., 1841, pl. xvi., f. 42 *a*, *b*, p. 30.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., f. 4, p. 224.
Upper Devonian (Pilton Beds). [7157] Brushford, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., figs. 7, 7*a*, p. 224.
Upper Devonian (Pilton Beds). [7156] Braunton.

Crinoid, Auxiliary arm of
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 3, p. 346.
Caradoc. [7390] Desertcreat, Tyrone.

Crinoidal Column.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 2 *a*, *b*, p. 345.
Caradoc. [7392] Desertcreat, Tyrone.

Cupressocrinus crassus, Goldfuss.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 4, 4 *a*, p. 207.
Middle Devonian. [7087] Newton Bushel.

Cyathocrinus acinotubus ? Angelin.
F. A. Bather, Ann. Mag. Nat. Hist., vol. ix., 1892, p. 211. (Text figure 5.)
Wenlock Limestone. [7375] Dudley.

Cyathocrinus ? ellipticus, Phillips. T.
J. Phillips, Pal. Foss., 1841, pl. xvi., f. 49 *a–d*, p. 32.
Upper Devonian. [7147] Petherwin, Cornwall.

Cyathocrinus ? macrodactylus, Phillips, T.
J. Phillips, Pal. Foss., pl. xv., f. 41*e*, p. 29. Refigured as **Taxocrinus macrodactylus**: G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiii., f. 2, p. 215.
Upper Devonian (Pilton Beds). [7148] Pilton, North Devon.

Digitized by Google

Gilbertsocrinus simplex, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 5 *a*, *b*, p. 351.
Carboniferous Limestone. [7615] Fermanagh.

Glyptocrinus ? (Cœlocrinus) basalis, M'Coy.
J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4, 4 *a*, p. 283.
Caradoc. [7388] Guilsfield, near Meifod.
J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4 *b*, p. 283.
Caradoc. [7389] Gwrelddian, Llanwddyn.

Hexacrinus depressus, Austin. T.
T. and T. Austin, "Recent and Fossil Crinoidea," 1843, pl. vi., f. 2 *a–e*, p. 49.
Middle Devonian. [7089, 7091] Newton Bushel.

Hexacrinus interscapularis (Phillips).
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., f. 2; pl. xxii., figs. 2, 2 *a*, p. 190. (See also *Platycrinus interscapularis*.)
Middle Devonian. [1549, 7090] Bradley and Newton Abbot.

Hexacrinus macrotatus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *a*, *d*, p. 50.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 6, p. 192. (See also *Platycrinus tuberculatus*).
Middle Devonian. [6880] Newton Bushel.

Hexacrinus melo, *vide* **Platycrinus interscapularis.**

Hexacrinus ? pentangularis, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vii., f. 1 *a–c*, p. 51. Refigured as **Hexacrinus quintangulus**, G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., figs. 6, 6 *a*, *b*, p. 198.
Middle Devonian. [7095] Newton Bushel.

Hexacrinus perarmatus, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 10, p. 194.
Middle Devonian. [6879] Newton Bushel.

Hexacrinus quintangulus, *vide* **Hexacrinus ? pentangularis.**

Hexacrinus Vicarii, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 4, p. 197. (See also *Platycrinus pentangularis ?*).
Middle Devonian. [7093] Newton Bushel.

Hydreionocrinus ? globularis, de Koninck. T.
L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv., 1858, pl. ii., figs. 1–4, p. 93. "The Geologist," vol. i, 1858, pl. iv., figs. 1–4, p. 180.
Carboniferous Limestone (*Productus*-bed). [7440] Lesmahagow.

Hydreionocrinus scoticus, de Koninck. T.
L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv, 1858, pl. ii., figs. 6, 7; p. 93. "The Geologist," vol. i., 1858, pl. iv., f. 6, 7, p. 179.
Carboniferous Limestone (*Productus*-bed). [7439] Lesmahagow.

Platycrinus granulatus, Miller.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 2 *m*, p. 33.
Carboniferous Limestone. [7630] Hook Point, Wexford.

Platycrinites granulatus, Miller.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 4, p. 350.
Carboniferous Limestone. [7631] Hook Point, Wexford.

Digitized by Google

Platycrinus interscapularis, Phillips. T.
J. Phillips, Pal. Foss., pl. xiv., f. 39 *a–d*, p. 28. Refigured as **Hexacrinus melo**, Austin, **T.** "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 1 *a–e*, p. 48; and as **Hexacrinus interscapularis**: G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., figs. 1, 1 *a–d*, p. 190.
Middle Devonian. [7088] Newton Bushel.

Platycrinites lævis, Miller.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 1 *d*, *e*, *f*, *i*, *l*, *n*, p. 8.
Carboniferous Limestone. [7632–7634] Hook Point, Wexford.

Platycrinus pentangularis? Phillips.
J. Phillips, Pal. Foss., pl. lx., f. 29**, p. 135. Refigured as **Hexacrinus Vicarii**, G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 5, p. 197.
Middle Devonian. [7092, 7093] Newton Bushel.

Platycrinites spinosus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 2 *p*, *q*, p. 19.
Carboniferous Limestone. [7663] Hook Point, Wexford.

Platycrinites trigintidactylus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 1 *b*, p. 30.
Carboniferous Limestone. [7664] Hook Point, Wexford.

Platycrinus tuberculatus? Phillips.
J. Phillips, Pal. Foss, pl. lx., f. 39,* p. 134. Refigured as **Hexacrinus macrotatus**, Austin, **T.**, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *b*, p. 50; G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 8, p. 192.
Middle Devonian. [7094] Newton Bushel.

Poteriocrinus conicus, Phillips.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 3 *c*, p. 82.
Carboniferous. [7606] Clifton, Bristol.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 12, p. 350.
Carboniferous. [7602] Fermanagh.

Poteriocrinus dactyloides, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 7, p. 85.
Carboniferous Limestone. [7604] Hook Point, Wexford.

Poteriocrinus isacobus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. viii., f. 4 *a–d*, p. 74.
Carboniferous Limestone. [7605] Hook Point, Wexford.

Poteriocrinus latifrons, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 4, p. 82,
Carboniferous Limestone. [7603] Mendip Hills.

Poteriocrinus quinquangularis, Austin. T.
T. and T. Austin, 'Rec. and Foss. Crinoidea," 1843, pl. x., f. 2 *a–e*, p. 80
Carboniferous Limestone. [7608–7611] Hook Point, Wexford.

Poteriocrinus radiatus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 1 *a*, *b*, p. 79.
Carboniferous Limestone. [7614] Hook Point, Wexford.

Digitized by Google

Poteriocrinus rostratus, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. ix., f. 2 *b*, *c*, p. 75.
Carboniferous Limestone. [7613, 7612] Hook Point, Wexford.

Poteriocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxv., f. 4. p. 228.
Upper Devonian (Marwood Beds). [7155] Braunton Down, N. Devon.

Poteriocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 9, 9 *a*, p. 228.
Upper Devonian (Marwood Beds). [7154] Braunton Down, N. Devon.

Rhodocrinus (Acanthocrinus) sp.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 6, 6 *a*, p. 204.
Middle Devonian. [7096] Newton Bushel.

Rhodocrinus ?
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., f. 3 *a–d*, p. 217.
Upper Devonian (Marwood Beds). [7142, 7143] North Devon.

Scaphiocrinus ? inordinatus ? Whidborne.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., f. 7, p. 230.
Upper Devonian (Marwood Beds). [7151] Braunton, North Devon.

Scaphiocrinus ? plumifer, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 1, 1 *a*, p. 228.
Upper Devonian (Marwood Beds). [7153] Braunton, North Devon.

Scaphiocrinus sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., figs. 8, 8 *a*, p. 231.
Upper Devonian (Marwood Beds). [7152] Braunton, North Devon.

Sphærocrinus geometricus (Goldfuss).
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., f. 8, p. 211.
Middle Devonian. [6878] Newton Bushel.

Taxocrinus macrodactylus (Phillips).
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiii., figs. 3, 3*a*, 4, 4*a*, p. 215. (See also *Cyathocrinus ?*).
Upper Devonian (Marwood Beds). [7149, 7150] North Devon.

Trochocrinites lævis, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 1, p. 345.
Caradoc. [7391] Desertcreat, Tyrone.

Edrioasteroidea.

Agelacrinites buchianus, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxiii., figs. 1-14, p. 521. Figs. 2 and 3 refigured, J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xx., f. 13, p. 291. Figs. 1–9 refigured as **Edrioaster**, F. A. Bather, Geol. Mag., 1900, plates viii-x. and text figures, pp. 193–204. Fig. 1 refigured, O. Jaekel, "Stammesgeschichte der Pelmatozoen," vol. i., 1899, p. 45 (text figure).
Caradoc. [7403, 7404] 2 mls. W. of Ysputty Evan, Denbighshire.

Digitized by Google

Edrioaster, *vide* **Agelacrinites.**

Lepidodiscus Milleri, Sharman and Newton. **T.**
G. Sharman and E. T. Newton, Q. J. G. S., vol. xlviii., 1892, pl. ii., p. 150.
Carboniferous Limestone. [7662] River Irthing, Cumberland.

ASTEROIDEA.

Asterias primæva, Salter. *Vide* **Palæaster obtusus.**

Eugaster ? perarmatus (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., figs. 6, 6 *a*, p. 209.
Upper Devonian (Pilton Beds). (7163] Braunton Down.

Palæaster asperrimus, Salter. **T.**
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 325.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 2, p. 289.
Caradoc. [7435] Quakers' Burial Ground, Welshpool.

Palæaster coronella, Salter. **T.**
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
Upper Llandovery. [7402] Gunwick Hill, Malvern.

Palæaster longimanus, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 1, 1 *a*, 2, 3, 3 *a*, *b*, p. 204.
Upper Devonian (Pilton Beds). [7162–7164]
Park near Braunton, and Baggy Point, North Devon.

Palæaster (Uraster) obtusus, Forbes.
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 1, p. 289.
Caradoc. (See also *Uraster*.) [7436] Moel-y-Garnedd.

Protaster granifer (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 5, 5 *a*, 6, 6 *a*, p. 207.
Upper Devonian (Pilton Beds). [7165, 7166] North Devon.

Protaster ? (Drepanaster) scabrosus, Whidborne, var. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxviii., figs. 1, 1 *a*, *b*, 2, 2 *a*, *b*, p. 208.
Upper Devonian. [7167, 7168] Croyde, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxix., figs. 2, 2 *a*, p. 208.
Upper Devonian (Pilton Beds). [7169] Braunton Down, N. Devon.

Uraster obtusus, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, p. 463.
E. Forbes, M. G. S., Decade 1, 1849, pl. 1, f. 3, p. 2.
Caradoc. (See also *Palæaster*.) [7437] Waterford.

OPHIUROIDEA.

Ophiurella ? gregaria (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., lii., 1898, pl. xxviii., f. 3, p. 210.
Upper Devonian (Pilton Beds). [7162] Braunton Down, N. Devon.

Digitized by Google

ECHINOIDEA.

Cidaris benburbensis, Portlock. T
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., figs. 10, 10 *a*, *b*, 11, p. 352.
Carboniferous Limestone. [7659] Benburb, Tyrone.

Protocidaris acuaria (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxv., figs. 1, 1 *a*, *b*, 2, 2 *a*, p. 203.
Upper Devonian (Pilton Beds). [7158, 7159] East of Barnstaple.

Lepidesthes ? devenicans, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., figs. 1, 2; pl. xxv., f. 3 *a–f*, p. 200.
Upper Devonian (Pilton Beds). [7160, 7161] East of Barnstaple.

Melonites Etheridgii, Keeping. T.
W. Keeping, Q. J. G. S., vol. xxxii., 1876, figs. 1–6, p. 397.
Carboniferous Limestone. [6577] Clitheroe.

Palæchinus gigas, M'Coy.
R. T. Jackson, Bull. Geol. Soc. America, vol. vii., 1896, pl. vii., figs. 38, 39, p. 204.
Carboniferous Limestone. [6576] Clitheroe, Lancashire.

Digitized by Google

Digitized by Google

INDEX.

A

Aberfeldy, 167.
Achilty, 111.
Agates, Indian, 93.
Agriculture, 16, 33, 53, 98, 103, 127, 132, 147, 148, 193.
Alderton, 59, 60.
Allen, H. A., 91, 95, 200, 204.
Alness, 3.
Alnöite, 69.
Alluvium, 10.
Ammanford, 43.
Amman Valley, 51.
Amphibolite, 101, 120, 121, 122.
Analyses, 72–91.
Andesites, 134, 135, 136, 138.
Aqueduct of Birmingham Waterworks, 60.
Arenig, 17, 65.
Argyll, 118, 149.
Arran, 178.
Asteroidea, 210.
Atholl Forest, 157.
Atkinson, J., 75.
——— M. W., 75.
Augen-gneiss, 106, 108, 111.
Augite-diorite, 97, 140, 141.
Axholme, Isle of, 64.
Axminster, 54–56, 58.
——— and Lyme Regis Railway, 53.
Aymestry Limestone, 62.

B

Bagshot Beds, 56–58.
Bala Beds, 61.
Barrow, G., 66, 92, 151, 152 157–165, 183.
Barry, C., 83.
Bell, A., 185.
Bemrose, H. H. Arnold, 10.
Ben Vrackie, 172.
Biddulph Valley, 6, 7, 12.
Bindown, 29, 30.
Birmingham Waterworks, 60.
Bishopston, 52.
———Beds, 41.
Black Mountains, 50.
Blackadder, 180.
Blair Atholl, 157, 168.
Blake, J. H., 5, 92.
Bollin Valley, 12–14.
Boulders in Drift, Cheshire, 11.
Boulder Clay, Upper and Lower, 191, 193.
Boulder Clay, Derbyshire, 9; Cheshire, 10; Scotland, 114, 127, 132, 152–155; Dublin, 185 *et seq.*
Bovey Basin, 57, 58.
Boveysand, 29.
Boyd, L., 93.
Brecknock Beacons, 50.
Brickmaking, 16.
Brixham, 28.
Broadford Beds, 143.
Brögger, Dr. W. C., 70.
Brownstones, 39, 40.
Brynamman, 43.
Buchite, 152.
Bunter, 8.
Bynack, 160.
Bynea Brick-works, 53.

C

Caban Group, 61.
Camborne, 23, 25.
Cambrian, 131.
Camptonite, 69, 70.
Cantrill, T. C., 5, 34–44, 50, 51, 60–64, 71, 80.
Carbis Bay, 19, 33.
Carboniferous, 5, 30, 63.
——— Limestone, 40.
Carmarthen Fans, 39, 50.
Carmarthenshire, 34.
Carn Bica, 53.
Carn Menelez, 22–24.
Carn Mosyn, 50.
Carrickmines, 191.
Catalogue of Types and Figured Specimens, 200, 204.
Cefn-y-Bryn, 40.
Cennen, 38, 39, 50, 51.
Cerig Gwynion Grits, 61
Champernowne, A., 28.
Chard, 58.
Chelius, C., 71.

Digitized by Google

Chellaston, 8, 9.
Chert, 40, 42, 92, 146, 149.
Cheshire, 5, 8, 10, 15, 16.
China Stone, 26.
Churnet Valley, 13.
Clay-boulders, 191.
Clay, Puddling, 53.
Clayton, E. G., 83.
Clee Hill, 63.
Clints, 125.
Close, Rev. M. H., 185.
Clough, C. T., 92, 95–99, 114, 117, 118, 130, 146, 149, 152, 155, 181.
Coals, Analyses of, 72.
Coal Measures, 42, 63.
Coal-seams, 43 *et seq.*
Cobban, A. McD., 5.
Combe Pyne Hill, 54, 56–59.
Congleton, 10, 11.
Copper-ore, 157.
Cornbrash, 59.
Cornwall, 16.
Craig, E. H. Cunningham, 68, 157, 165–175, 181.
Crampton, Dr. C. B., 95, 96, 104–107, 109, 113, 116, 177, 181.
Cretaceous, 3, 92, 145, 146.
Crewe, 10, 11.
Cribarth, 35.
Crinan, 118.
Crinoidea, 206.
Crowle, 64, 65.
Crowstones, 16.
Crush conglomerates, 17, 129, 130.
Cunningham Craig, E. H., 68, 157, 165–175, 181.
Cuillin Hills, 86, 87.
Cystidea, 204.

D

Dana, J. D., 90.
Dane Valley, 10–13, 15, 16.
Dartmouth Slates, 27–30.
Deeley, R. M., 9.
De la Beche, Sir H. T., 2, 17, 21, 30, 41, 42, 83.
Derby, 8, 9.
Derbyshire, 5, 8, 9.
Derwent Valley, 9, 10.
Desclоiseaux, A., 90.
Devonian, 27 ; fossils, 91, 92.
Devonshire, 16.
Didymograptus-shales, 35–37.
Diorite, 98, 125, 164, 165.
Dixon, E. E. L., 20, 23, 25, 58.
Dodder Valley, 187–189, 194, 195.
Doggers, 60.
Dolomite, 84, 131.
Downton, 62.
Downtonian, 178.
Drift deposits. See Glacial.
Drumlins, 186.
Dublin District, 183.
Dunite, 149.
Dust, Wind-borne, 33.
Dyffryn Flags, 60.
Dykes of gravel and clay, 191.
Dykes, Igneous, 98, 121–123, 137, 140, 149–151.

E

Echinodermata, Palæozoic, 204.
Echinoidea, 211.
Economics, 53, 103, 156.
Edrio-asteroidea, 209.
Elan, 60, 61.
Elles, G. L., 182.
Elvans, 25.
England and Wales, Field-work, 4.
Eocene, 58.
Eolithic Implements, 59.
Epidiorite, 120, 124, 127, 168, 177.
Epworth, 64.
Erewash Valley, 10.
Eskers, 4, 187, 194, 195, 197.
Essexite, 70.

F

Falar District, succession of schists in, 161.
Falmouth, 33.
——— Series, 17, 18, 34.
Farewell Rock, 42
Faults, 35, 43, 48, 49.
Fannich Forest, 96, 99, 115.
Felsite, 70.
Feochan, 132.
Ffairfach-grit, 35, 36.
Fire-bricks, 53.
Flett, Dr. J. S., 65–71, 81, 84, 85, 88, 89, 101, 102, 108, 109, 121, 141, 168.
Flood-gravels, 195.
Fluvio-glacial deposits, 10.
Frankley, 60, 63.
Forest Marble, 59, 60.
Forsterite, 132.
Fourchite, 70.
Fowey, 27–29.
Fox, H., 17.
Foyaite, 70.

G

Galena, 99.
Garnbica, 40.
Gawsworth, 13, 14.
Geikie, Sir A., 84, 146, 178.
——— Prof. J., 14.
Gibson, W., 5, 8, 10, 11, 16, 64, 95.

Digitized by Google

Glacial Drift of Derbyshire, 9; of Cheshire, 10; of Ireland, 4, 185-199; of Scotland, 114, 127, 132, 152; of South Wales, 50.
Glamorganshire, 34.
Glan-Morlais, 47.
Glen Cannich, 101.
—— Cona, 120.
—— Creran, 126.
—— Feshie, 157, 165.
—— Finnan, 121.
—— Nevis, 152.
—— Scaddle, 120.
—— Strathfarrar, 101, 103.
—— Urquhart, 101.
Glenasmole, 188, 199.
Glenelg, 3, 96–98, 114.
Glover, M. F., 64.
Gneisses, 67.
Godolphin, 23, 26.
Godrevy, 20, 33.
Golden Grove, 37.
Goodchild, J. G., 182, 183.
Goole and Marshland railway, 64.
Goostrey, 11, 15.
Gorges, Water-cut, 188, 199.
Gorran Haven, 17.
Gotham, 8, 9, 10.
Gower, 2, 38, 39, 41, 42, 44, 48, 49, 52.
Grainger, Canon, 185.
Grammysia-beds, 37.
Granite of Cornwall, 2, 20.
——— of Highlands, 3, 68.
——— of Ben Cruachan, 140.
——— of East Ross-shire, 109, 111.
——— of Glen Domhain, 142.
——— of Glenelg-Ratagan, 97.
——— of Inchbae, 106.
——— of Lismore, 140.
——— of Meall Tionnail, 166
——— North of Tilt Valley, 164.
Grant Wilson, J. S., 70, 118–123, 126–130, 149–152, 154–157, 175.
Graptolites, 61, 62.
Great Oolite, 60, 144.
Green Beds, 66–68, 167, 168.
Greenstone, Cornwall, 19, 20.
Green, U., 28.
Grindlestone Edge, 7, 12.
Grovesend Veins, 44, 45.
Gulval Downs, 21, 25.
Gunn, W., 95, 96, 99, 100, 104, 106, 110, 112, 115, 116, 178, 183.
Gwastaden Group, 60, 61.
Gwennap, 23.
Gwinear, 23, 25.
Gypsum, 8, 9.

H

Hagley, 63.
Haldon, 57.
Halesowen Sandstones, 63.
Harker, A., 86, 87, 118, 131, 132, 139, 146, 147, 151, 183.
Harris, G. F., 83.
Haxey, 64.
Hayle, 19, 20, 25, 33.
——— Sandstone, 2, 17, 19, 20.
Heaton, 6, 7, 12.
Highlands, Scottish, 3, 65, 95, 118, 157.
Hill, J. B., 17, 18, 22–26, 30, 34, 66, 67, 95, 128, 183.
Hinch, Mr., 198.
Hinde, Dr. G. J., 92, 146.
Hind, Dr. Wheelton, 177, 182.
Hinton Sand, 60.
Hinxman, L. W., 58, 66, 67, 86, 95, 96, 100, 101, 102, 111, 115.
Honestones, 159, 160.
Honiton, 58.
Hornblendite, 97, 109.
Horne, Dr. J., 1, 95, 96, 99, 100, 115, 157.
Hornfels, 108, 125, 126, 129, 164, 173.
Horton, 6, 7.
Howe, J. A., 5, 8, 11, 12, 15.
Howth, 187, 197, 198.
Hullavington, 59, 60.
Hull, Prof. E., 185.
Hutchings, W. M., 152.

I

Ice-sheet, 187, 193.
Inchbae, 106.
Inferior Oolite, 143.
Interglacial, 9.
Inverguseran, 98, 114.
Inverlael Forest, 96, 104.
Inverness-shire, 95, 96, 101, 112, 115, 149.
Ireland, Field-work in, 183.

J

Jarrowite, 89, 90.
Joints, 125.
Judd, Prof. J. W., 109.
Jukes-Browne, A. J., 5.
Jurassic, 8, 9, 92, 142-145.

K

Kames, 116, 187.
Kea, 25.
Kelly, J., 185.
Kennal Vale, 24.
Kentallenite, 141.
Kersantite, 69.
Keuper, 54, 64.

Digitized by Google

Kidston, R., 177–180.
Kilbride, 124.
Kildermorie, 108.
Kill of the Grange, 191, 193, 194.
Killas, 19, 21, 22, 25.
Killiecrankie, 173.
Killiney, 191–194.
Kilmartin District, 126; Physical Features of, 127; Succession of metamorphic rocks in, 128; Glacial phenomena of, 154, 156.
Kilmore, 153.
Kilroe, J. R., 183, 184, 189–194.
Kimeridgian, 145.
Kinahan, G. H., 185.
Kincardine, 110, 117.
Kingsbridge, 28.
Kingshouse, 137.
Kingswear, 27.
Kitchen-midden, 198.
Kitchin, Dr. F. L., 91, 145.
Knapdale, 118.
Knighton, 62.
Knoll-structure, 186.
Kynaston, H., 67, 118, 123–126, 134–140, 183.

L

Laccolite, of Ben Vrackie, 172, 173.
Lacustrine clay, 10, 14.
Lamplugh, G. W., 1, 5, 91, 183–189, 197.
Lamprophyres, 69, 70, 98, 101, 102, 137, 141, 165.
Land's End, 2, 18, 19, 20, 21, 26, 33.
Landslips, 54, 55.
Lapworth, Prof. C., 182.
————, H., 60, 61.
Lask Edge, 6.
Lee, 6, 7.
Lelant, 19, 33.
Levant Mine, 22.
Lewisian, 96, 97, 99.
Lias, 8, 9, 92, 142.
Library, 94.
Liffey, 186, 187, 188, 189, 194–196.
Lime, 53, 125, 156.
Limestone-breccia, 141.
Lismore, 124, 153, 155.
Lizard, 18.
Llandilo, 35, 36.
———— Beds, 35, 36, 37.
Llandovery Beds, 60, 61.
Llan-Elen Sandstones, 48.
Llanelly, 42, 44, 45, 52.
Llanvirn Beds, 35.
Lletty Grit, 37.
Loch Awe, 66, 67, 124.
—— Bracadale, 147.
—— Brittle, 147.
—— Eil, 118, 119.
—— Linnhe, 118, 123.
Loch Scamadale, 124, 134, 136.
—— Sheil, 118.
—— Staffin series, 144.
Lodes, 25.
Logan, Sir W. E., 42.
Loughor, 44, 45, 47, 51.
Looe, 28, 29, 91, 92.
Lorne, 118, 132, 155.
Lower Compton, 31.
Lower Lias, 8, 9, 92, 142.
——— Limestone Shales, 40.
Ludlow Beds, 37, 40, 62.
Lyme Regis, 58, 59; Railway, 53.

M

Macaulay, F. W., 63.
Macclesfield, 10, 12, 13.
Macconochie, A., 177, 178, 181.
McHenry, A., 183, 184, 194–196.
McKie, J., 62.
Magnesian Limestone, Weathering of, 83.
Maiden Newton, 58.
Malachite, 157.
Malchite, 3, 70, 121, 123.
Manganese, 157.
Mansergh, J., 5.
Maps, England and Wales, 4, 94; Scotland, 183; Ireland, 199.
——, Six-inch Reference, England and Wales, 94.
Marr, J. E., 36.
Meadfoot Beds, 28, 29.
Meall Uaine, 170.
Memoirs, England and Wales, 4, 95.
Metalliferous veins, 25.
Metamorphic Rocks, 96, 118, 137.
Metamorphism, 66, 67, 108, 125, 126, 131, 139, 141, 163, 167; around Cornish granite, 20, 22, 23.
Mewslade Bay, 50.
Mica-trap, 98, 101, 111.
Mickleover, 9.
Middle Glacial, 191.
Middlewich, 10.
Miers, Prof. H. A., 90.
Miller, H., 109.
Millstone Grit, 6, 42.
Minerals from Skye and Ross-shire, 86.
Mineral veins, 25.
Minette, 69.
Mining information, 2.
Moine Schists, 96, 97, 98, 100, 101, 104, 105, 110, 120, 157, 165, 166.
Monchiquite, 69.
Monckton, H. W., 5, 92.
Montpelier Hill, 188, 199.
Mounts Bay, 32.
Muff, H. B., 118, 124, 126-130, 140, 149–151, 153–156.
Mullion Island, 17, 18.

Digitized by Google

Mumbles Head Beds, 41.
Museum, Edinburgh, 182.
——— of Practical Geology, 91–94, 200.
Mylor Series, 17, 18, 19, 20, 34.

N

Nare Point, 17, 18.
Neath, 45, 46.
Newlyn, 19, 32, 88.
Newton, E. T., 91–93, 95, 145, 146, 149, 181, 183.
Newton Abbot, 57.
——— Nottage, 41.
Newtonmore, 166.
Norham Bridge, 179.

O

Oban, 153.
Odenwald, 3.
Old Hill Marls, 63.
Old Red Sandstone, 37, 38, 62, 111–114, 132.
Ophicalcites, 132.
Ophiuroidea, 210.
Ordovician, 16, 34, 37, 61.
Osann, A, 71.
Ostrea Sowerbyi, 59, 60.
Over-thrusts, 34.
Oxfordian, 144.
Oxwich Head, 41.
——— Point, 50.
Oystermouth, 41.

P

Paignton, 28.
Paint-manufacture, 49, 53.
Palæontological Work, 91, 177.
Passage Beds, 37, 38, 39.
Paton, J., 90.
Peach, B. N., 118, 124, 126–130, 132–134, 142, 149–151, 153–156, 177, 179, 181–183.
Peat, 16, 65, 99, 103, 127, 133, 147, 155, 157.
Pegmatite, 86, 97, 101, 105, 107, 120, 122.
Pencarrow Head, 29, 30.
Pencatite, 132.
Penlee, 32.
Pennant Series, 44.
Pennine Hills, 12, 15.
Penryn, 25.
——— granite, 23.
Penybont Tunnel, 61, 62.
Penzance, 19, 21, 32, 33.
Peover, 11, 15.
Peridotite, 149.
Permian, 7, 8, 63, 64.
Perthshire, 157, 167, 168–177.
Petrographical Work, 65.
Phillack, 19, 20.
Phillips, R., 83.
Phœnix Park, 197.
Phyllite, 128, 129.
Phyllocarida, Fossil, 200.
Picotite, 86.
Picrite, 149.
Pitlochry and Blair Atholl District, succession of Schists in, 172.
Plants from Reading Beds, 92.
Pleistocene (Derbyshire), 9; (Cheshire), 10. See also Glacial Drift.
Plinthite, 148.
Pliocene, 31.
Plymouth, 29, 30.
Pocock, T. I., 5, 12–15.
Pollard, Dr. W., 56, 71–91.
Polperro, 27, 29.
Porphyrite, 98, 137, 140.
Port Eynon, 49, 53.
Portscatho Series, 17, 18, 34.
Portland Stone, 83.
Post Glacial, 117.
Pottery, Collection of, 93.
Praeger, R. Ll., 185, 191.
Pseudogaylussite, 89.
Publications, England and Wales, 94; Scotland, 183; Ireland, 199.
Pyroxenite, 97.

Q

Quartz-felsite, 98.
Quartz-porphyry, 166.
Quartzite, Central Highlands, 162, 169, 171, 172, 176.
Quethiock, 27.

R

Radiolarian beds, 17, 42.
Radley, E. G., 71.
Railway-cuttings, 5, 53, 121, 122.
Raised Beaches 32, 49, 117, 195, 198.
Rathfarnham, 187, 194.
Reade, T. M., 185.
Reading Beds, 92.
Recent Deposits, 15.
Reedness, 65.
Reid, C., 4, 10, 16–26, 31–34, 57, 58, 88.
Renwick, 90.
Rhætic Beds, 8, 9, 55.
Rhayader, 60, 61.
Rhossili Bay, 52.
Ringmore, 29.

Digitized by Google

River gravels, 9.
Road-metal, 16, 156.
Roberts, G. E., 63.
——— T., 36.
Rosenbusch, Prof. H., 70, 71.
Ross-shire, 95, 96, 100, 102, 104, 115.
Rottenstone, 36, 40, 41, 80.
Rudler, F. W., 90, 93, 94.
Rudyard, 6, 7.
Rushton, 1, 6–8.
——— Spencer, 5.

S

St. Erth, 19, 31.
St. Ives Bay, 18, 33.
Sandbach, 10, 11.
Sand, Combe Pyne, Composition of, 56.
Salt-regions, 16.
Scalpay, 145.
Schists, 67.
Sconser, 142.
Scotland, Field-work in, 95.
Scottish Highlands, 65, 95, 118, 157.
Scyelite, 106, 109.
Sections published, England and Wales, 94.
Senni Beds, 39.
Seward, A. C., 181.
Seyler, C. A., 72.
Seymour, H. J., 102, 183, 184, 196, 197.
Shelly drift, 187, 192, 193, 197.
Siddington, 14.
Silica sand, 41.
Sills, 147, 148, 172–174.
Silurian, 16, 35, 36, 60.
Sinfin Moor, 10.
Sketty, 51, 52.
Skye, 86, 87, 92, 118, 131, 132, 142–149.
Smith, C. H., 83.
Smith, Wm., 60, 83.
Soay, 3, 130, 149, 152, 155.
Soils, 16, 33, 53, 98, 103, 127, 132, 147, 148, 193, 194.
Sollas, Prof. W. J., 185.
Southern Uplands, 65, 66.
South Wales Coals, 72.
——— Direct Railway, 59.
——— District, 34.
——— Rottenstone, 80.
Spangle schists, 107.
Spessartite, 69, 70.
Spirorbis-limestone, 64.
Staddon grits, 29, 30.
Staffordshire, 5, 8.
Stourbridge, 63.
Strahan, A., 4, 32, 34, 35, 38–40, 44–53, 59, 72, 95.
Strangways, C. Fox, 4, 5, 8–10.
Strathaird, 142.
Strathglass, 101, 102, 103.
Strathrusdale, 96, 106, 116.
Strath Tummel, 175.
Strathvaich, 96, 105, 112, 116.
Strollamus, 142, 143, 144.
Struan, 160.
Struy, 101.
Suishnish, Skye, 92.
Sulphur well, 99.
Sutherlandshire, 95.
Swansea, 42, 44, 45, 47, 51, 52.
Syenite, 97.
Symes, R. G., 136, 142, 150, 151.

T

Tait, D., 131, 143, 177, 178, 181.
Tarannon Beds, 61.
Tarf, 157.
Tawney, E. B., 49.
Taynuilt, 134.
Teall, J. J. H., 1–4, 30, 70, 129, 131, 132, 164.
Terraces of gravel, 9, 10, 13, 15.
Tertiary, 31, 56; igneous rocks, 87, 114, 147–152.
Theralite, 70.
Thomas, H. H., 34–39, 56, 57.
Ticknock Valley, 196.
Tiddeman, R. H., 34, 38–42, 52, 95.
Tilestones, 37, 38, 53.
Tilt, 159.
Titterstone Clee Hill, 62.
Tolka river, 198.
Tonalite, 141.
Torquay, 28, 91, 92.
Torridonian, 130–131.
Towy Valley, 50.
Trapp, 38, 39.
Traquair, Dr. R. H., 177, 181, 182.
Trechmann, Dr. C. O., 89–91.
Tregantle, 29.
Treluswell, 24.
Tremolite limestone, 158, 161, 170, 172.
Trent Valley, 8, 9, 10.
Trias, 8, 49, 54, 63, 64, 142.
Trichrug, 36,
——— Beds, 37.
Trimpley, 63.
Troctolite, 149, 152.
Truro, 25.
Tuedian, 179.
Type Specimens, Catalogue of, 200, 204.

Digitized by Google

U

Uplyme, 58.
Upper Greensand, 55, 56, 58, 59.
Upper Lias, 143.
Upper and Lower Boulder Clay, 191, 193.
Ussher, W. A. E., 27–31, 58, 91, 92, 95.

V

Vale of Neath, 35.
Valley gravels, 9, 54.
Veryan Beds, 17, 18.
Vogesite, 69, 141.
Volcanic rocks of Blackmount, 137 ; of Lorne, 132 ; of Skye, 87, 147.

W

Wales, South, District, 34.
Warmingham Moss, 16.
Water Supply, 16, 32, 103, 125.
Watts, Prof. W. W., 61.
Wavellite, 42.
Wearde Beds, 2.
——— Efford, 31.
Weathering of Magnesian Limestone, 83.
Weaver Valley, 11.
Wedd, C. B., 5–8, 11, 12, 15, 95, 118, 131, 142–146.
Welsh Moor, 52.
Wenlock Beds, 37, 61.
Wheelock, 11.
Whidborne, Rev. G. F., 28.
Whitaker, W., 59.
Whiteadder, 179–181.
Whitesand Bay, 25.
Wilkinson, B. S. N., 34, 39, 40, 49, 50, 52, 53.
Williams, G. H., 90.
Wilson, J. S. G., 70, 118–123, 126–130, 149–152, 154–157, 175.
Wood, E. M. R., 61, 182.
Woodward, H. B., 1, 4, 5, 53–60, 95.
Wootton Bassett, 59.
Worms Head, 50.
Wright, W. B., 183, 184, 196–199.
Wyre Forest, 62, 63.

Y

Yarcombe, 58.
Yoredale Sandstones, 6.

Z

Zennor, 21.
Zoisite-schist, 121.

Digitized by Google

SHEET MEMOIRS OF THE GEOLOGICAL SURVEY—*continued.*

E, SE - NORWICH. By H. B. WOODWARD. 7*s.*
W - ATTLEBOROUGH. By F. J. BENNETT. 1*s.* 6*d.*
W - E. DEREHAM. By J. H. BLAKE. 1*s.* 6*d.*
- YARMOUTH and LOWESTOFT. By J. H. BLAKE. 2*s.*
- CROMER. By C. REID. 6*s.*
W, SW - FAKENHAM, WELLS, &c. By H. B. WOODWARD. 2*s.*
- BORDERS OF THE WASH. By W. WHITAKER and A. J. JUKES-BROWNE. 3*s.*
- S. W. LINCOLNSHIRE, &c. By A. J. JUKES-BROWNE and W. H. DALTON. 4*s.*
E - NOTTINGHAM. By W. T. AVELINE. (2nd Ed.) 1*s.*
W - RHYL, ABERGELE, and COLWYN. By A. STRAHAN. (Notes by R. H. TIDDEMAN.) 1*s.* 6*d.*
E - FLINT, MOLD, and RUTHIN. By A. STRAHAN. (Parts by C. E. DE RANCE.) 4*s.* 6*d.*; *Supplement* 2*d.*
W - PRESCOT, LANCASHIRE. By E. HULL. (3rd Ed. With additions by A. STRAHAN.) 3*s.*
W - CHESTER. By A. STRAHAN. 2*s.*
W, SW - STOCKPORT, MACCLESFIELD, CONGLETON, and LEEK. By E. HULL and A. H. GREEN. 4*s.*
E - PARTS of NOTTINGHAMSHIRE and DERBYSHIRE. By W. T. AVELINE. (2nd Ed.) 6*d.*
E - PARTS of NOTTINGHAMSHIRE, YORKSHIRE, and DERBYSHIRE. (2nd Ed.) By W. T. AVELINE.
- LINCOLN. By W. A. E. USSHER, A. J. JUKES-BROWNE and A. STRAHAN. 3*s.*
- EAST LINCOLNSHIRE. By A. J. JUKES-BROWNE. 3*s.* 6*d.*
- N. LINCOLNSHIRE and S. YORKSHIRE. By W. A. E. USSHER [and Others]. 2*s.*
W - WAKEFIELD and PONTEFRACT. By A. H. GREEN. 6*d.*
W - BARNSLEY. By A. H. GREEN. 9*d.*
W - OLDHAM. By E. HULL. 2*s.*
- PART of the YORKSHIRE COALFIELD. By A. H. GREEN, J. R. DAKYNS and J. C. WARD. 1*s.*
E - DEWSBURY, &c. By A. H. GREEN, J. R. DAKYNS, J. C. WARD, and R. RUSSELL. 6*d.*
E - BOLTON, LANCASHIRE. By E. HULL. 2*s.*
E - The COUNTRY between LIVERPOOL and SOUTHPORT. By C. E. DE RANCE. 3*d.*
E - SOUTHPORT, LYTHAM, and SOUTH SHORE. By C. E. DE RANCE. 6*d.*
W - The COUNTRY between BLACKPOOL and FLEETWOOD. By C. E. DE RANCE. 6*d.*
W - SOUTHERN PART of the FURNESS DISTRICT in N. LANCASHIRE. By W. T. AVELINE. 6*d.*
E - BRADFORD and SKIPTON. By J. R. DAKYNS, C. FOX-STRANGWAYS, R. RUSSELL, and W. H. DALTON. 6
W - NORTH and EAST of HARROGATE. By C. FOX-STRANGWAYS. 6*d.*
E - The COUNTRY between YORK and MALTON. By C. FOX-STRANGWAYS. 1*s.* 6*d.*
W - N. and E. of LEEDS, and near TADCASTER. By W. T. AVELINE, A. H. GREEN (and others).
E, 94 W - COUNTRY between YORK and HULL. By J. R. DAKYNS, C. FOX-STRANGWAYS, and A. G. CAMERON. 1*s.*
W - DRIFFIELD. By J. R. DAKYNS and C. FOX-STRANGWAYS. 9*d.*
E - BRIDLINGTON BAY. By J. R. DAKYNS and C. FOX-STRANGWAYS. 1*s.*
W, SE - SCARBOROUGH and FLAMBOROUGH HEAD. By C. FOX-STRANGWAYS. 1*s.*
W - WHITBY and SCARBOROUGH. By C. FOX-STRANGWAYS and G. BARROW. 1*s.* 6*d.*
- NEW MALTON, PICKERING, and HELMSLEY. By C. FOX-STRANGWAYS. 1*s.*
E - ESKDALE, ROSEDALE, &c. By C. FOX-STRANGWAYS, C. REID, and G. BARROW. 1*s.* 6*d.*
W, SW - NORTHALLERTON and THIRSK. By C. FOX-STRANGWAYS, A. G. CAMERON, and G. BARROW. 1*s.* 6*d.*
W - INGLEBOROUGH. By J. R. DAKYNS, R. H. TIDDEMAN, W. GUNN, and A. STRAHAN. 2*s.*
W - MALLERSTANG. By J. R. DAKYNS, R. H. TIDDEMAN (and others). 3*s.* 6*d.*
- KIRKBY LONSDALE and KENDAL. By W. T. AVELINE, T. MC K. HUGHES, and R. H TIDDEMAN. 2*s.*
E - KENDAL. By W. T. AVELINE and T. MC K. HUGHES. 2nd Ed. by A. STRAHAN. 2*s.*
E - NORTHERN PART of the ENGLISH LAKE DISTRICT. By J. C. WARD. 9*s.*
W - APPLEBY, ULLSWATER, and HAWESWATER. By J. R. DAKYNS, R. H. TIDDEMAN, and J. G. GOODCHILD. 1*s.* 6*d.*
W, SE - NORTH CLEVELAND. By G. BARROW. 1*s.* 6*d.*
- CARLISLE. By T. V. HOLMES. 1*s.* 3*d.*
E - OTTERBURN and ELSDON. By HUGH MILLER. 2*s.* 6*d.*
E - CHEVIOT HILLS By C. T. CLOUGH. 1*s.* 6*d.*
W - PLASHETTS and KIELDER. By C. T. CLOUGH. 1*s.*
W - WOOLER and COLDSTREAM. By W. GUNN and C. T. CLOUGH. 1*s.* 6*d.*
W - NORHAM and TWEEDMOUTH. By W. GUNN. 6*d.*
E - COAST SOUTH of BERWICK-ON-TWEED. By W. GUNN. 9*d.*
E - BELFORD, HOLY ID, and FARNE ISLANDS. By W. GUNN. 2*s.* 6*d.*
New Series) ATHERSTONE and CHARNWOOD FOREST. By C. FOX-STRANGWAYS. 2*s.*
") ABERGAVENNY. By A. STRAHAN and W. GIBSON. 2*s.*
") NEWPORT MON. By A. STRAHAN. 2*s.*
") CARDIFF. By A. STRAHAN and T. C. CANTRILL. 2*s.* 3*d.*
") RINGWOOD. By C. REID. 1*s.*
") SOUTHAMPTON. By C. Reid. 1*s.* 6*d.*
") EXETER. By W. A. E. USSHER. 2*s.*
") DORCHESTER. By C. REID. 1*s.*
") BOURNEMOUTH. By C. REID. 4*d.*
") BOGNOR. By C. REID. 6*d.*
") EASTBOURNE. By C. REID. 6*d.*

COAL-FIELDS AND OTHER MINERAL DISTRICTS.—Scale, six inches to a mile.

he Coal-fields and other mineral districts of the N. of England are in part published on a scale of six inches to a mile to 6*s.* each. M.S. Coloured Copies of other six-inch maps, not intended for publication, are deposited for reference eological Survey Office, 28, Jermyn Street, London.

THE IRON ORES OF GREAT BRITAIN.

t I. The North and North Midland Counties of England (*Out of print*). Part II. South Staffordshire. Price ... Part III. South Wales. Price 1*s.* 3*d.* Part IV. The Shropshire Coal-field and North Staffordshire. 1*s.* 3*d.*

Digitized by Google